INFLUENCE OF COLLISION INTENSITY ON THE ANALYSIS OF VEHICULAR SIDE-IMPACT ACCIDENT DATA

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SUMMARY

The investigation of vehicle accidents is important because background data is obtained concerning real world events that can be used in the development and evaluation of vehicle safety programs and standards. The side-impact subset of vehicle accidents is significant in terms of occupant injury severity because of the inherent small crush distance available between the exterior of the vehicle and the passenger compartment.

This study introduces a new approach to the analysis of vehicle accident data. The accident data contained in the Multidisciplinary Accident Investigation File is categorized by type of accident and then by a collision intensity parameter, which is a measure of the magnitude of the momentum of the two colliding bodies, within each type of accident. Several data elements were selected from the side-impact, side-damage subset of automobile-to-automobile accidents to evaluate the following parameters of interest: side of impact, presence of side reinforcement beams, make of automobile by manufacturer, usage of occupant restraining belts, and occupant seating position and location.

The results of this study show that this approach is invaluable in the analysis of accident data. It was developed for the analysis of side-impact accident data, however, it

should be equally powerful for the analysis of accident data in general. The parameters of interest were found to be significant, but the degree of their significance was found to depend upon the presence of a particular combination of the parameters and not upon the presence of the parameters individually.

CHAPTER I

INTRODUCTION

Purpose of Vehicle Accident Investigations

The investigation of vehicular accidents is vital in that background data is obtained concerning real-world events that can be used in the development and evaluation of safety programs and standards. In 1968, the United States Department of Transportation began a program of awarding contracts to investigate vehicular accidents from a multi-disciplinary standpoint. The exact structure of each of the teams varied somewhat, but did include technical representatives from the following disciplines: Automotive Mechanics, Mechanical Engineering, Civil Engineering, Psychology, Sociology, and Medicine.

Multidisciplinary Accident Investigation Teams

The Multidisciplinary Accident Investigation (MDAI) teams selected accidents somewhat arbitrarily, but primarily focused on accidents involving at least one recent year model, so that federally regulated safety features could be evaluated, and on accidents which resulted in occupant injury. The Collision Performance and Injury Report [1] (CPIR), Revision 3, was completed for at least one of the vehicles in the accident and was submitted to the National Highway

Traffic Safety Administration (NHTSA) for inclusion in the MDAI File, which is managed by the Highway Safety Research Institute (HSRI) at the University of Michigan.

Organization of Multidisciplinary Accident Investigation File

The MDAI File [2] is organized into three analysis files--the Vehicle File, the Occupant File, and the Injury File. The analysis files are so arranged that the data elements from the Vehicle File are repeated in the Occupant File, and then the data elements from both files are repeated in the Injury File. The MDAI File structure is summarized in Table 1.

Table 1. Organization of MDAI File

File	Variables	Description
For each Vehicle	V1 through V576	Vehicle Data Elements
For each Occupant	V1 through V576	Vehicle File
	V577 through V636	Occupant Data Elements
For each Injury	V1 through V576	Vehicle File
	V577 through V636	Occupant File
	V637 through V647	Injury Data Elements

One particular type of vehicular accident which is of considerable interest is the side-impact collision because of the inherent small crush distance available between the exterior of the vehicle and the passenger compartment. Recent studies [3] have shown that side-impact collisions are rather significant in terms of their injury production capabilities. Considerable interest in side-impact collisions has also been shown by the HSRI and the Motor Vehicle Manufacturers Association (MVMA). One report [4] by HSRI used various statistical techniques to evaluate the effectiveness of side door reinforcement beams. That study served as an excellent reference and showed that certain logical trends can be seen in the MDAI File. Nevertheless, that study demonstrated that any results obtained from the MDAI File, as it is presently organized, would be basically inconclusive if a strict statistical approach were used. However, from an engineering point of view, the argument may be made that data should be primarily organized to reflect the physical phenomena controlling a study. Only then will statistical methods contribute to greater confidence in the results. Subsequently, it became a basic premise of this writer that vehicular accidents should be categorized by a collision intensity parameter in order for accident data to be meaningfully analyzed.

CHAPTER II

CATEGORIZATION BY COLLISION INTENSITY

Basis for Collision Intensity

The collision intensity was selected as the basis for data organization because it provides a measure of the severity of the impact between two bodies. Basically, it is a measure of the magnitude of the momentum of the two bodies during the period of initial impact. The momentum is not conserved throughout the accident because of the various dissipative forces, however, it can be assumed to be conserved during the period of initial impact. The vehicle momentum is a vector quantity in the direction of the vehicle velocity and, due to the various vehicle orientations possible during impact, may not be in the same direction as the principle force which acts on the vehicle to cause the vehicle damage and occupant injury. Therefore, the component of momentum along the common line of action, which is the line of the opposing principle forces, is used.

The collision intensity parameter thus makes it possible to analyze, on a meaningful basis, accident data from a variety of accidents. The common element which makes the analysis meaningful is the value of the parameter because a particular value is possible through several combinations of vehicle weights and speeds. As long as the parameter values are comparable, then the accident data are comparable.

The vehicles involved in an accident are referred to as the 'Case Vehicle' and the 'Other Vehicle' in the MDAI File. The 'Case Vehicle' is the one for which a CPIR form is submitted by the investigation team. There must be at least one 'Case Vehicle' in an accident and may be as many as deemed appropriate by the investigation team. The 'Other Vehicle' is, as the name implies, the remaining vehicle in an accident. For each 'Case Vehicle', there will be as many 'Other Vehicles' as there are remaining vehicles in the accident. The terms are purely relative and refer only to whether or not that vehicle is the vehicle of interest for a particular CPIR form.

Definition of Collision Intensity Parameter

The definition of the collision intensity parameter is given by the following equation:

$$CI = A[M_1 v_1 \cos\theta_1 + M_2 v_2 \cos\theta_2]$$

where

A = Equivalent Resiliency Coefficient

M_1, M_2 = Mass of 'Case Vehicle' and 'Other Vehicle', respectively

v_1, v_2 = Speed at first impact of 'Case Vehicle' and

'Other Vehicle', respectively

θ_1, θ_2 = Orientation angle of 'Case Vehicle' and 'Other Vehicle', respectively.

The Equivalent Resiliency Coefficient is a factor which depends upon the type of object contacted and is a function of the energy absorbing abilities of the colliding bodies. The purpose of this factor is to relate the collision intensities of the various types of collisions to a comparative scale so that the accident data from these collisions can be meaningfully analyzed. The values for this factor have not yet been developed, however, for the purpose of this study, a value of 1.0 was selected for the automobile-to-automobile collision. It is anticipated that the complete range of values would be from a low of nearly zero for the automobile-to-pedestrian collision to a high of 2.0 for the classic automobile-to-barrier collision.

The values for the vehicle masses are obtained from the vehicle weight data elements. The vehicle weights listed in the MDAI File are extracted from various automobile distributor association publications by the investigation teams and are basically shipping weights.

The vehicle speeds at first impact are determined by the investigation teams based on the accident data and/or driver or witness testimony. For the purpose of this study, the vehicle speeds were assumed to be velocities directed toward the front of the vehicle unless the collision orientation dictated otherwise.

The orientation angles are based on the o'clock directions of the principle force acting on each vehicle at impact, and are measured clockwise in 30 degree increments from the 12 o'clock position. The principle force is the force that caused the crush and sheet metal displacement and is the resultant of forces on the vehicle at the point of application. The clock face is assumed to be in a plane parallel to the horizontal plane of the vehicle and aligned so that 12 o'clock refers to a frontal directed force applied at the area of deformation. The o'clock directions are determined by the investigation teams and are listed as digits 1 and 2 of the 7 digit Collision Deformation Classification [5] (CDC). The orientation angles and the vehicle orientations associated with each combination of the o'clock directions of force for a two vehicle collision are presented in Appendix A.

A summary of the factors used in determining the collision intensity and their corresponding data elements from the Vehicle File is presented in Table 2. A sample calculation for the collision intensity of an actual collision is presented as Appendix B.

When calculating the collision intensity parameter, it was assumed that only one collision occurred during the accident sequence and that the total vehicular damage and occupant injury were a result of that collision. This

Table 2. Data Elements Used in Calculation of Collision Intensity

Factor	Data Element: Case Vehicle	Data Element: Other Vehicle
Vehicle Model	V118	V88
Vehicle Mass	V121	V91
Speed at First Impact	V75	V77
Clock Direction	V137	V99
CDC	V143	V105

assumption was necessary because, although the MDAI File lists as many as four objects contacted during the accident sequence, it is not arranged so that the percentage of vehicle momentum dissipated during each collision can be determined. In order to determine a complete collision intensity for an accident sequence, it would be necessary to consider each of the objects contacted, the speeds and angles at which they collide, and their energy absorbing abilities.

Application of Collision Intensity to Accident Data

So that the collision intensity parameter could be applied to the analysis of side-impact accident data, side-impact accidents were defined as those where the o'clock directions of primary force for the 'Case Vehicle' were

02, 03, 04, 08, 09 and 10. This set of accidents was further restricted to include only those that had side-damage involving the passenger compartment so as to eliminate those accidents where the primary force was not transmitted directly to the passenger compartment. This side-impact, side-damage subset was then classified according to type of collision and to intensity level within each type.

The types of collisions, automobile-to-automobile, automobile-to-truck, automobile-to-fixed object, etc., are based on the object contacted by the vehicle of interest. This classification is believed to be necessary because the vehicle kinematics and dynamics after impact and the energy absorbed by the vehicle of interest are dependent upon the type of object contacted.

The collision intensity level groupings for each type of collision are made arbitrarily based on the distribution of values throughout the range of values. The purpose of the collision intensity parameter is to identify collisions of comparable intensity so that the accident data from those collisions can be meaningfully analyzed. The distribution of values for the automobile-to-automobile collisions is given as Appendix C. To facilitate the analysis of the accident data, these collisions were grouped as shown in Table 3.

Table 3. Collision Intensity Groups

Group	Parameter Value
1	0-50
2	51-100
3	101-150
4	151-200
5	200-250

Moderate	0-150
Severe	151-250

CHAPTER III

ANALYSIS OF AUTOMOBILE-TO-AUTOMOBILE ACCIDENT DATA

Method of Approach

In order to analyze the accident data within each of the Collision Intensity Groups, various variables, or data elements, were selected from the MDAI File which could be used to evaluate parameters of interest. The average number of inches of sheet metal crush on the side of impact was selected from the Vehicle File and the average value of the Occupant Abbreviated Injury Scale (A.I.S.) and the number of injured body regions per occupant were selected from the Occupant and Injury Files.

The sheet metal crush variable was selected because it is rather objective in nature, i.e., can be physically measured by the investigation teams, and can be a valid measure of the rigidity and energy absorbing ability of the side structure of the automobiles. The average value of the Damage Extent Zone, which is the seventh digit of the C.D.C., was also analyzed, but this variable is somewhat subjective in nature because it involves nine zones equally divided through one half the length or width of the automobile, and the zone selection is based primarily on sheet metal crush. Nevertheless, the analysis of the Damage

Extent Zone is of interest and is therefore included as Appendix F.

The occupant A.I.S. was selected because it is the measure adopted by the American Medical Association to express the overall severity of injuries received by an occupant. A detailed explanation of the A.I.S. is contained in Reference 2.

The number of injured body regions per occupant was selected because it is a function of the occupant and vehicle kinematics throughout the accident sequence. The number of types of injuries per occupant was also analyzed. However, whenever a body region contacts an object, more than one type of injury may result. Therefore, it is believed that the number of injured body regions per occupant is a more consistent measure. Nevertheless, the analysis of the number of types of injuries per occupant is of interest and is therefore included as Appendix H.

This approach to the analysis is summarized in Table 4.

Parameters Evaluated

The parameters of interest chosen for evaluation in this study are side of impact, the presence of side reinforcement beams, the make of automobile by manufacturer, the usage of occupant restraining belts, and the occupant seating position and location.

The side of impact is determined by the investigation teams and recorded as the third digit of the CDC. The 'Case

Table 4. Method of Approach to Analysis of Automobile-to-Automobile Subset of Side-Impact Accident Data

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Vehicle File

- Average Number of Inches of Sheet Metal Crush

Occupant and Injury Files

- Average Value of Occupant A.I.S.
  - By All, Restrained and Unrestrained Occupants
  - By Seating Position and Location and Automobile Manufacturer
- Number of Injured Body Regions per Occupant

Vehicle' in the automobile-to-automobile subset are thus divided into two groups--those involving a left impact collision and those involving a right impact collision.

Federal Motor Vehicle Safety Standard (FMVSS) 214 requires that side door reinforcement beams be installed on all vehicle openings used for passenger egress on vehicles manufactured after January 1, 1973. The automobile manufacturers began installing the side reinforcement beams on a model-by-model basis beginning as early as 1969, therefore the various models and the model year when the side beams were introduced are given as Appendix D.

The make of automobile is determined by the investigation teams and recorded as the second and third digits of the five digit Vehicle Make/Model Code. The United States manufacturers represented in the automobile-to-automobile subset are General Motors Corporation, Ford Motor Company, and Chrysler Corporation. A summary of the 'Case Vehicles' in this subset is included in Appendix E.

The usage of currently installed occupant restraining belts is determined by the investigation teams and recorded in the Occupant File. For the purpose of this study, this data element was recoded to indicate only whether the restraining belts were or were not used. Due to the small number of occupants who were using the belts, a distinction was not made as to whether the belts were lap belt only or both lap and torso belts. A summary of the occupants in the

'Case Vehicles' is included in Appendix G.

The original occupant seating position and location are determined by the investigation teams and recorded in the Occupant File. The seating position refers to the left, center, or right position on the seat and the seating location refers to the front or rear seat.

The analysis of the Vehicle File will be made using five individual collision intensity levels and two consolidated groups--moderate, which consists of levels 1, 2 and 3, and severe, which consists of levels 4 and 5. However, due to the rather small number of either automobiles or occupants in several of the categories, the analysis of the Occupant and Injury Files will be made using the moderate and severe intensity groups.

Comparison of Sheet Metal Crush

The results of the analysis of the sheet metal crush on the side of impact are presented in Tables 5-8. Considering all the automobiles, Table 5, the group average values for automobiles with side beam are generally lower than those for automobiles without side beam. However, for the moderate group, the average value for automobiles with side beam is only marginally lower than that for automobiles without side beam, whereas for the severe group there appears to be a significant difference between the two values. This trend would appear to indicate that the side beam does provide some benefit to the side structure of the automobile and that this benefit is more pronounced at the higher intensity levels. The group average values also generally increase with increasing collision intensity levels. This trend would appear to indicate that the number of inches of sheet metal crush is a function of the collision intensity.

Considering General Motors automobiles, Table 6, the group average value for automobiles with side beam is the same as the value for automobiles without side beam in the moderate intensity group. However, the group average value for automobiles with side beam is lower than that for automobiles without side beam in the severe intensity group. This trend would appear to indicate that the side beam is of no significant benefit at the moderate intensity levels, but that it does provide some benefit at the severe intensity levels for General Motors automobiles.

Considering Ford automobiles, Table 7, the average values for automobiles with side beam are generally lower than those for automobiles without side beam. This trend would appear to indicate that the side beam does provide some benefit for Ford automobiles.

Considering Chrysler automobiles, Table 8, although the number of Chrysler automobiles with side beam is rather small, the average values do not appear to indicate that the side beam is of any significant additional benefit to Chrysler automobiles. However it is significant to note that the

Table 5. Average Number of Inches of Sheet Metal Crush on Side of Impact by Side of Impact and With and Without Side Beam

All Automobiles

Collision Intensity Group	Side of Impact	With Side Beam				Without Side Beam			
		No. Autos	Side Average	No. Autos	Group Average	No. Autos	Side Average	No. Autos	Group Average
1	Left	3	7.7	9	9.3	13	13.5	26	12.4
	Right	6	10.2			13	11.2		
2	Left	9	11.9	26	12.9	24	13.9	51	12.4
	Right	17	13.5			27	11.0		
3	Left	5	10.8	16	15.3	13	16.5	20	18.5
	Right	11	17.4			7	22.0		
4	Left	2	12.5	3	12.7	2	16.5	9	20.3
	Right	1	13.0			7	21.4		
5	Left	3	19.0	5	23.0	3	27.0	7	28.8
	Right	2	29.0			4	30.3		
Moderate	Left	17	10.8	51	13.0	50	14.5	97	13.6
	Right	34	14.2			47	12.7		
Severe	Left	5	16.4	8	19.2	5	22.8	16	24.1
	Right	3	23.6			11	24.6		
Total	Left	22	12.1	59	13.9	55	15.3	113	15.1
	Right	37	14.9			58	15.0		

With: 34% of All Autos
Without: 66% of All Autos

Table 6. Average Number of Inches of Sheet Metal Crush on Side of Impact by Side of Impact and With and Without Side Beam

General Motors Corporation Automobiles

Collision Intensity Group	Side of Impact	With Side Beam				Without Side Beam			
		No. Autos	Side Average	No. Autos	Group Average	No. Autos	Side Average	No. Autos	Group Average
1	Left Right	3 5	7.7 9.8	8	9.0	5 2	15.2 8.5	7	13.3
2	Left Right	9 14	11.9 13.9	23	13.1	6 10	15.3 9.4	16	11.6
3	Left Right	3 8	11.3 17.4	11	15.7	3 2	13.3 22.0	5	16.8
4	Left Right	1 1	20.0 13.0	2	16.5	1 3	25.0 23.0	4	23.5
5	Left Right	3 2	19.0 29.0	5	23.0	1 3	13.0 30.3	4	26.0
Moderate	Left Right	15 27	10.9 14.2	42	13.0	14 14	14.9 11.1	28	13.0
Severe	Left Right	4 3	19.3 23.6	7	21.2	2 6	19.0 26.7	8	24.8
Total	Left Right	19 30	12.7 15.1	49	14.2	16 20	15.4 15.8	36	15.6

GM: 49% of All Autos

With: 58% of GM Autos
Without: 42% of GM Autos

Table 7. Average Number of Inches of Sheet Metal Crush on Side of Impact by Side of Impact and With and Without Side Beam

Ford Corporation Automobiles

Collision Intensity Group	Side of Impact	With Side Beam				Without Side Beam			
		No. Autos	Side Average	No. Autos	Group Average	No. Autos	Side Average	No. Autos	Group Average
1	Left			1	12.0	7	12.3	16	11.8
	Right	1	12.0			9	11.4		
2	Left			2	7.5	14	14.0	18	14.2
	Right	2	7.5			4	14.8		
3	Left	1	6.0	3	15.0	6	20.0	8	22.0
	Right	2	19.5			2	28.0		
4	Left	1	5.0	1	5.0	1	8.0	3	15.3
	Right					2	19.0		
5	Left					2	34.0	2	34.0
	Right								
Moderate	Left	1	6.0	6	12.0	27	14.9	42	14.8
	Right	5	13.2			15	14.5		
Severe	Left	1	5.0	1	5.0	3	25.3	5	22.8
	Right					2	19.0		
Total	Left	2	5.5	7	11.0	30	15.9	47	15.7
	Right	5	13.2			17	15.1		

Ford: 31% of All Autos

With: 13% of Ford Autos
Without: 87% of Ford Autos

Table 8. Average Number of Inches of Sheet Metal Crush on Side of Impact by Side of Impact and With and Without Side Beam

Chrysler Corporation Automobiles

Collision Intensity Group	Side of Impact	With Side Beam				Without Side Beam			
		No. Autos	Side Average	No. Autos	Group Average	No. Autos	Side Average	No. Autos	Group Average
1	Left					1	14.0	3	13.3
	Right					2	13.0		
2	Left			1	19.0	4	11.5	17	11.2
	Right	1	19.0			13	11.1		
3	Left	1	14.0	2	13.5	4	13.8	7	15.6
	Right	1	13.0			3	18.0		
4	Left							2	21.5
	Right					2	21.5		
5	Left							1	30.0
	Right					1	30.0		
Moderate	Left	1	14.0	3	15.3	9	12.8	27	12.6
	Right	2	16.0			18	12.4		
Severe	Left							3	24.3
	Right					3	24.3		
Total	Left	1	14.0	3	15.3	9	12.8	30	13.7
	Right	2	16.0			21	14.2		

Chrysler: 20% of All Autos

With: 9% of Chrysler Autos
Without: 91% of Chrysler Autos

average value for Chrysler automobiles without side beam is lower than that for General Motors automobiles with side beam and essentially the same as Ford automobiles with side beam.

Comparison of Occupant Injury Severity

The analysis of the Occupant A.I.S. was made in two stages and the results are presented in Tables 9-11 and 12-20, respectively. The first stage primarily measures the effectiveness of the usage of occupant restraining belts in side-impact collisions and secondarily considers the side of impact and the presence of side reinforcement beams. The second stage primarily considers the significance of seating position and location and the side of impact and secondarily the usage of occupant restraining belts and the presence of side reinforcement beams. The first stage includes collisions from both the moderate and severe intensity levels, whereas the second stage includes only the moderate group because of a more restrictive categorization and the resulting fewer number of occupants in each of the categories. The severe intensity group for the second stage is of interest however, and is therefore included as Appendix I.

Considering all occupants, Table 9, the average values for occupants in automobiles with side beam are generally lower than those for occupants in automobiles without side beam. This trend would appear to indicate that the side beam does provide some benefit in terms of occupant injury severity. Also, the group average values generally increase with increasing collision intensity levels. This trend would appear to indicate that occupant injury severity is also a function of collision intensity.

Considering restrained occupants, Table 10; the average value for occupants in automobiles with side beam is higher than that for occupants in automobiles without side beam in the moderate intensity group, whereas it is lower in the severe intensity group. Also, the average values generally increase with increasing collision intensity levels.

Considering unrestrained occupants, Table 11; the average values for occupants in automobiles with side beam are generally lower than those for occupants in automobiles without side beam. Also, the average values generally increase with increasing collision intensity levels.

Comparing restrained and unrestrained occupants; the average value for restrained occupants in automobiles with side beam is essentially the same as that for unrestrained occupants in automobiles with side beam in both the moderate and severe intensity groups. However, the average value for restrained occupants in automobiles without side beam is lower than that for unrestrained occupants in automobiles without side beam in the moderate intensity group and higher than that in the severe intensity group.

Although the analysis thus far appears to indicate

Table 9. Average Value of Occupant A.I.S. by Side of Impact and With and Without Side Beam

All Occupants

Collision Intensity Group	Side of Impact	With Side Beam				Without Side Beam			
		No. Occ.	Side Avg.	No. Occ.	Group Avg.	No. Occ.	Side Avg.	No. Occ.	Group Avg.
1	Left Right	4 12	.75 1.00	16	.94	25 21	1.56 1.24	46	1.41
2	Left Right	15 29	1.33 1.35	44	1.34	47 46	1.30 1.17	93	1.24
3	Left Right	11 21	1.18 1.24	32	1.22	20 14	1.65 1.29	34	1.50
4	Left Right	3 2	1.33 2.00	5	1.60	2 14	4.50 3.43	16	3.56
5	Left Right	8 4	1.88 2.25	12	2.00	5 5	4.00 6.20	10	5.10
Moderate	Left Right	30 62	1.20 1.24	92	1.23	92 81	1.45 1.21	173	1.34
Severe	Left Right	11 6	1.73 2.17	17	1.88	7 19	4.14 4.16	26	4.15
Total	Left Right	41 68	1.34 1.32	109	1.33	99 100	1.64 1.77	199	1.70

With: 35% of all occupants
Without: 65% of all occupants

Table 10. Average Value of Occupant A.I.S. by Side of Impact and With and Without Side Beam

Restrained Occupants

Collision Intensity Group	Side of Impact	With Side Beam				Without Side Beam			
		No. Occ.	Side Avg.	No. Occ.	Group Avg.	No. Occ.	Side Avg.	No. Occ.	Group Avg.
1	Left	1	1.00	3	.67			3	1.33
	Right	2	.50			3	1.33		
2	Left	3	1.00	5	.80	15	1.00	19	.95
	Right	2	.50			4	.75		
3	Left			4	2.25	4	1.50	7	1.29
	Right	4	2.25			3	1.00		
4	Left	1	1.00	1	1.00			6	4.83
	Right					6	4.83		
5	Left	7	1.86	8	2.00			2	7.50
	Right	1	3.00			2	7.50		
Moderate	Left	4	1.00	12	1.25	19	1.11	29	1.07
	Right	8	1.38			10	1.00		
Severe	Left	8	1.75	9	1.89			8	5.50
	Right	1	3.00			8	5.50		
Total	Left	12	1.50	21	1.52	19	1.11	37	2.03
	Right	9	1.56			18	3.00		

Restrained: 19% of all occupants
With: 36% of restrained occupants
Without: 64% of restrained occupants

Table 11. **Average Value of Occupant A.I.S. by Side of Impact and With and Without Side Beam**

Unrestrained Occupants

Collision Intensity Group	Side of Impact	With Side Beam				Without Side Beam			
		No. Occ.	Side Avg.	No. Occ.	Group Avg.	No. Occ.	Side Avg.	No. Occ.	Group Avg.
1	Left	3	.67	13	1.00	24	1.50	42	1.38
	Right	10	1.10			18	1.22		
2	Left	12	1.42	39	1.41	28	1.50	68	1.32
	Right	27	1.41			40	1.20		
3	Left	8	1.38	24	1.17	16	1.69	27	1.56
	Right	16	1.06			11	1.36		
4	Left	2	1.50	4	1.75	2	4.50	10	2.90
	Right	2	2.00			8	2.50		
5	Left	1	2.00	4	2.00	5	4.00	8	4.50
	Right	3	2.00			3	5.33		
Moderate	Left	23	1.30	76	1.26	68	1.55	137	1.39
	Right	53	1.25			69	1.23		
Severe	Left	3	1.67	8	1.88	7	4.14	18	3.61
	Right	5	2.00			11	3.27		
Total	Left	26	1.35	84	1.32	75	1.79	155	1.65
	Right	58	1.31			80	1.51		

Unrestrained: 78% of all occupants
With: 35% of unrestrained occupants
Without: 65% of unrestrained occupants

that the occupant restraining belts may be of no significant benefit to occupants in automobiles with side beam in the moderate intensity group, there are differences in the values for left and right impact. Therefore, the analysis was expanded to include seating position and location as well as side of impact in order to determine if the significance of the restraining belts is being masked by the significance of side of impact.

Considering restrained occupants in automobiles with side beam, Tables 12 and 13; the average values for occupants sitting on the side of impact are higher than those for occupants sitting on the opposite side. Considering restrained occupants in automobiles without side beam, Tables 14 and 15; the average values for occupants sitting on the side of impact are higher than those for occupants sitting on the opposite side in the left impact collisions. The right impact collisions were not compared because there was only one occupant on the side of impact. Considering the restrained occupants sitting on the side of impact for left impact, the average values for occupants in automobiles with side beam are lower than those for occupants in automobiles without side beam. Considering restrained occupants sitting on the opposite side, the average values for occupants in automobiles with side beam are lower than those for occupants in automobiles without side beam. Therefore, the side of impact appears to be the most significant parameter, however, the side beam does appear to provide some benefit for restrained occupants.

Considering unrestrained occupants in automobiles with side beam, Tables 16 and 17; the average values for occupants sitting on the side of impact are higher than those for occupants sitting on the opposite side. Considering unrestrained occupants in automobiles without side beam, Tables 18 and 19; the average values for occupants sitting on the side of impact are higher than those for occupants sitting on the opposite side. Considering unrestrained occupants sitting on the side of impact, the average values for occupants in automobiles with side beam are lower than those for occupants in automobiles without side beam. Considering unrestrained occupants sitting on the opposite side, the average values for occupants in automobiles with side beam are higher than those for occupants in automobiles without side beam. Therefore, the side of impact appears to be the most significant parameter, however, the side beam appears to be beneficial to unrestrained occupants sitting on the side of impact but detrimental to unrestrained occupants sitting on the opposite side.

Comparing the restrained occupants with the unrestrained occupants by seating position and location for each of the categories, the average values for restrained occupants are generally lower than those for unrestrained occupants. This trend would appear to indicate that the occupant restraining belts do provide some benefit to occupants in side impact

Table 12. Average Value of Occupant A.I.S. by Seat Position and Location and Automobile Manufacturer

Moderate Intensity
Restrained Occupants
With Side Beams
Left Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	3	1.33			1	0.00	4	1.00
	Ford								
	Chrysler								
	All	3	1.33			1	0.00	4	1.00
Rear	GM								
	Ford								
	Chrysler								
	All								
Total	GM	3	1.33			1	0.00	4	1.00
	Ford								
	Chrysler								
	All	3	1.33			1	0.00	4	1.00

Table 13. Average Value of Occupant A.I.S. by Seat Position and Location and Automobile Manufacturer

Moderate Intensity
Restrained Occupants
With Side Beams
Right Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	4	.50			2	2.00	6	1.00
	Ford					1	4.00	1	4.00
	Chrysler								
	All	4	.50			3	2.67	7	1.43
Rear	GM			1	1.00				
	Ford								
	Chrysler								
	All			1	1.00			1	1.00
Total	GM	4	.50	1	1.00	2	2.00	7	1.00
	Ford					1	4.00	1	4.00
	Chrysler								
	All	4	.50	1	1.00	3	2.67	8	1.38

Table 14. Average Value of Occupant A.I.S. by Seat Position and Location and Automobile Manufacturer

Moderate Intensity
Restrained Occupants
Without Side Beams
Left Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	4	1.25					4	1.25
	Ford	4	1.75			3	.33	7	1.14
	Chrysler	3	1.33			2	1.00	5	1.20
	All	11	1.45			5	.60	16	1.19
Rear	GM								
	Ford	1	1.00	1	0.00	1	1.00	3	.67
	Chrysler								
	All	1	1.00	1	0.00	1	1.00	3	.67
Total	GM	4	1.25					4	1.25
	Ford	5	1.60	1	0.00	4	.50	10	1.00
	Chrysler	3	1.33			2	1.00	5	1.20
	All	12	1.42	1	0.00	6	.67	19	1.11

Table 15. Average Value of Occupant A.I.S. by Seat Position and Location and Automobile Manufacturer

Moderate Intensity
Restrained Occupants
Without Side Beams
Right Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	2	1.00					2	1.00
	Ford	3	1.33					3	1.33
	Chrysler	4	.75			1	1.00	5	.80
	All	9	1.00			1	1.00	10	1.00
Rear	GM								
	Ford								
	Chrysler								
	All								
Total	GM	2	1.00					2	1.00
	Ford	3	1.33					3	1.33
	Chrysler	4	.75			1	1.00	5	.80
	All	9	1.00			1	1.00	10	1.00

Table 16. Average Value of Occupant A.I.S. by Seat Position and Location and Automobile Manufacturer

Moderate Intensity
Unrestrained Occupants
With Side Beams
Left Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	12	1.50	1	1.00	6	1.00	19	1.32
	Ford	1	0.00			1	1.00	2	.50
	Chrysler	1	1.00					1	1.00
	All	14	1.36	1	1.00	7	1.00	22	1.23
Rear	GM					1	3.00	1	3.00
	Ford								
	Chrysler								
	All					1	3.00	1	3.00
Total	GM	12	1.50	1	1.00	7	1.29	20	1.40
	Ford	1	0.00			1	1.00	2	.50
	Chrysler	1	1.00					1	1.00
	All	14	1.36	1	1.00	8	1.25	23	1.30

Table 17. Average Value of Occupant A.I.S. by Seat Position and Location and Automobile Manufacturer

Moderate Intensity
Unrestrained Occupants
With Side Beams
Right Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	23	1.30	3	1.33	8	1.50	34	1.35
	Ford	5	1.00			2	1.50	7	1.14
	Chrysler	2	1.00			2	1.00	4	1.00
	All	30	1.23	3	1.33	12	1.42	45	1.29
Rear	GM	2	1.50	2	1.00	1	1.00	5	1.20
	Ford	1	0.00					1	0.00
	Chrysler	1	1.00			1	1.00	2	1.00
	All	4	1.00	2	1.00	2	1.00	8	1.00
Total	GM	25	1.32	5	1.20	9	1.45	39	1.33
	Ford	6	.83			2	1.50	8	1.00
	Chrysler	3	1.00			3	1.00	6	1.00
	All	34	1.24	5	1.20	14	1.36	53	1.25

Table 18. Average Value of Occupant A.I.S. by Seat Position and Location and Automobile Manufacturer

Moderate Intensity
Unrestrained Occupants
Without Side Beams
Left Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	8	2.50			7	.57	15	1.60
	Ford	23	2.17	2	1.00	7	1.43	32	1.94
	Chrysler	5	1.80			2	1.00	7	1.57
	All	36	2.20	2	1.00	16	1.00	54	1.80
Rear	GM	1	1.00			2	.50	3	.67
	Ford	3	.67	2	.50	3	.33	8	.50
	Chrysler	1	1.00			2	.50	3	.67
	All	5	.80	2	.50	7	.43	14	.57
Total	GM	9	2.33			9	.56	18	1.45
	Ford	26	2.00	4	.75	10	1.10	40	1.65
	Chrysler	6	1.67			4	.75	10	1.30
	All	41	2.02	4	.75	23	.83	68	1.55

Table 19. Average Value of Occupant A.I.S. by Seat Position and Location and Automobile Manufacturer

Moderate Intensity
Unrestrained Occupants
Without Side Beam
Right Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	12	.92	1	1.00	7	1.14	20	1.00
	Ford	10	.80	1	3.00	5	1.80	16	1.25
	Chrysler	14	1.07	1	2.00	8	1.50	23	1.26
	All	36	.94	3	2.00	20	1.45	59	1.17
Rear	GM			2	1.00	3	2.00	5	1.60
	Ford	1	1.00			1	4.00	2	2.50
	Chrysler	1	1.00			2	1.00	3	1.00
	All	2	1.00	2	1.00	6	2.00	10	1.60
Total	GM	12	.92	3	1.00	10	1.40	25	1.12
	Ford	11	.82	1	3.00	6	2.17	18	1.39
	Chrysler	15	1.07	1	2.00	10	1.40	26	1.23
	All	38	.95	5	1.60	26	1.58	69	1.23

collisions, but that the measure of that benefit depends upon the side of impact and occupant seating position and location.

Comparison of Injured Body Regions

The occupant A.I.S. has proven to be an effective tool in the analysis of accident data, however, it does have two disadvantages that need to be considered. The selection of a particular value is based upon a somewhat subjective medical evaluation of the occupant's overall injury severity, and the occupant's injury severity depends upon that particular individual's susceptibility to injury. Therefore, the number of injured body regions per occupant was selected for the final analysis. This analysis is made using only drivers and right front passengers from the moderate intensity group. There is an average of only 1.8 occupants per automobile in the automobile-to-automobile subset, so these two seating locations include 82 percent of the occupants in the moderate intensity group. However, the analysis for the severe intensity group is of interest, and is therefore included as Appendix J.

Considering restrained drivers, Table 20; drivers of automobiles with side beam experience a <u>fewer</u> number of different injured body regions than do drivers of automobiles without side beam; the total numbers of injured body regions per occupant for drivers of automobiles with side beam are <u>lower</u> than those for drivers of automobiles without side beam;

and the total numbers of injured body regions per occupant for left impact are higher than those for right impact within each of the categories--with side beam and without side beam. These trends would appear to indicate that the side beam does provide some benefit for restrained drivers, and that the side of impact is a significant parameter.

Considering unrestrained drivers, Table 21; the total number for left impact is lower for drivers of automobiles with side beam than that for drivers of automobiles without side beam, however, the total number for right impact is higher for drivers of automobiles with side beam than that for drivers of automobiles without side beam; and the total numbers for left impact are higher than those for right impact for drivers of automobiles within each of the categories--with side beam and without side beam. These trends would appear to indicate that, for unrestrained drivers, the side of impact is a significant parameter, and that the side beam is beneficial to drivers involved in left impact collisions, but detrimental to drivers involved in right impact collisions.

Comparing restrained and unrestrained drivers; the total numbers for restrained drivers are lower than those for unrestrained drivers in automobiles with side beam in left and right impact, respectively; for drivers of automobiles without side beam, the total number for restrained drivers is lower than for unrestrained drivers for left impact but higher than for right impact. These trends would appear to indicate that restraining belts are beneficial to drivers of automobiles with side beam and to drivers of automobiles without side beam when the impact is on the driver's side, but detrimental to drivers of automobiles without side beam when the impact is on the opposite side.

Considering restrained right front passengers, Table 22; the total numbers for right impact are higher than those for left impact for passengers in automobiles in both categories--with side beam and without side beam. This trend would appear to indicate that the side of impact is a significant parameter.

Considering unrestrained right front passengers, Table 23; the total numbers for passengers in automobiles with side beam are lower than those for passengers in automobiles without side beam for left and right impact, respectively; and the total number for passengers in automobiles with side beam is higher for right impact than for left impact, while the total number for passengers in automobiles without side beam is essentially the same for right impact as that for left impact. These trends would appear to indicate that the side of impact is a significant parameter and that the side beam does provide some benefit to unrestrained right front passengers.

Comparing restrained and unrestrained right front passengers; for passengers in automobiles with side beam, the total numbers for left and right impact, respectively, are higher for restrained passengers than for unrestrained passengers; and for passengers in automobiles without side beam, the total numbers for left and right impact, respectively, are lower for restrained passengers than for unrestrained passengers. These trends would appear to indicate that restraining belts are detrimental to right front passengers in automobiles with side beam, but are beneficial to right front passengers in automobiles without side beam.

Table 20. Number of Injured Body Regions per Occupant by Side of Impact and With and Without Side Beam
Moderate Intensity
Restrained Drivers

Body Region	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
Internal Organ				.11
Brain			.09	
Face		.25	.27	.33
Head		.25	.27	.11
Neck	.33		.18	.22
Shoulder Girdle	.33		.18	.22
Right Upper Limb			.09	
Left Upper Limb			.36	.11
Chest and Upper Back			.27	.22
Lower Back	.33		.09	.11
Abdomen		.25	.18	.22
Pelvic Girdle	.33	.50	.54	.11
Right Lower Limb	.33	.25	.18	.33
Left Lower Limb	.33		.36	.44
Whole Body	.33			
Not Applicable		.50		.11
Total	2.33	2.00	3.09	2.67
No. Occupants	3	4	11	9

Restrained: 19% of MI Group Drivers
With: 26% of Restrained MI Group Drivers
Without: 74% of Restrained MI Group Drivers

Table 21. Number of Injured Body Regions per Occupant by Side of Impact and With and Without Side Beam
Moderate Intensity
Unrestrained Drivers

Body Region	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
Internal Organ	.21		.17	
Brain	.14	.10	.19	.11
Face	.14	.43	.36	.36
Head	.14	.40	.28	.22
Neck	.14	.27	.11	.11
Shoulder Girdle	.07	.13	.19	.03
Right Upper Limb	.07	.17	.17	.22
Left Upper Limb	.21	.17	.28	.08
Chest and Upper Back	.50	.27	.44	.08
Lower Back	.21	.03	.11	
Abdomen	.07	.03	.17	.11
Pelvic Girdle	.29	.03	.25	.06
Right Lower Limb	.29	.13	.22	.17
Left Lower Limb	.29	.27	.31	.14
Whole Body		.03		.08
Not Applicable	.14	.17	.11	.25
Total	2.93	2.63	3.36	2.06
No. Occupants	14	30	36	36

Unrestrained: 81% of MI Group Drivers
With: 38% of Unrestrained MI Group Drivers
Without: 62% of Unrestrained MI Group Drivers

Table 22. Number of Injured Body Regions per Occupant by Side of Impact and With and Without Side Beam
Moderate Intensity
Restrained Right Front Passengers

Body Region	With Side Beam Left Impact	With Side Beam Right Impact	Without Side Beam Left Impact	Without Side Beam Right Impact
Internal Organ		.33		
Brain		.33		
Face				
Head		.33	.60	
Neck		.33		
Shoulder Girdle				1.00
Right Upper Limb		.67		1.00
Left Upper Limb		.33	.20	
Chest and Upper Back		.33		
Lower Back		.33		
Abdomen				
Pelvic Girdle	1.00	.33		
Right Lower Limb		.67		
Left Lower Limb		.33		
Whole Body	1.00			
Not Applicable			.40	
Total	2.00	4.33	1.20	2.00
No. Occupants	1	3	5	1

Restrained: 15% of MI Group RFP
With: 40% of Restrained MI Group RFP
Without: 60% of Restrained MI Group RFP

Table 23. Number of Injured Body Regions per Occupant by Side of Impact and With and Without Side Beam
Moderate Intensity
Unrestrained Right Front Passengers

Body Region	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
Internal Organ				
Brain		.17	.13	.10
Face	.29	.25	.44	.40
Head	.29	.25	.19	.30
Neck		.25	.06	.05
Shoulder Girdle		.17	.19	.15
Right Upper Limb	.14	.25	.13	.10
Left Upper Limb	.29	.08	.19	.15
Chest and Upper Back	.14	.42	.19	.35
Lower Back	.14		.06	.20
Abdomen				.05
Pelvic Girdle	.14	.17		.15
Right Lower Limb	.29	.08	.31	.25
Left Lower Limb		.17	.38	.05
Whole Body		.08		
Not Applicable			.19	.10
Total	1.72	2.33	2.44	2.40
No. Occupants	7	12	16	20

Unrestrained: 85% of MI Group RFP
With: 35% of Unrestrained MI Group RFP
Without: 65% of Unrestrained MI Group FRP

CHAPTER IV

CONCLUSIONS

This analysis has been made using accident data from the MDAI File. This data has proven to be very useful, however, certain factors must be considered before the results can be meaningfully interpreted. The accidents investigated by the MDAI teams were not chosen completely at random, but rather on the basis of certain criteria established by the United States Department of Transportation. The accidents were selected from those which resulted in occupant injury and involved at least one late model vehicle. The accidents were investigated by various teams which consisted of members representing different fields of expertise. In other words, the accident data contained in the MDAI File does not represent the entire spectrum of accidents that occur to the total United States vehicle population. Nevertheless, the fact that these accidents did occur is a matter of record; and as long as the biases in the MDAI File are recognized and given proper consideration, then the analysis, and the results of that analysis, should be meaningful and valid.

The following conclusions are based on the procedure established for the application of the collision intensity parameter to the analysis of accident data.

(1) In order to properly analyze vehicular accident data, it is necessary to have categorized the accidents in terms of a collision intensity parameter.

(2) The categorization of accidents by collision intensity eliminates the influence of the alleged bias due to the exclusion of most non-injury producing accidents from the MDAI File.

(3) In order to properly interpret vehicular accident data, it is necessary to have given consideration to the engineering principles of kinematics and dynamics.

(4) The vehicle kinematics should be determined for all vehicles involved in an accident and for each collision that occurs in a multiple collision accident. The vehicle kinematics, both before and after each collision, are required so that a thorough dynamic and force analysis can be made and so that the accident sequence can be restructured.

(5) The terms 'Case Vehicle' and 'Other Vehicle', used respectively in the MDAI File to refer to each vehicle for which a case report is completed and to the remaining vehicle(s) in the accident, are misleading in that they connote importance to only one of the vehicles. The kinematics of both vehicles must be known before the forces acting on either can be determined and before the intensity of the collision can be calculated. In terms of vehicle kinematics and dynamics, all vehicles involved in an accident are equally important.

Although sufficient data is not available for all of the categories for all of the collision intensity levels, the following trends are identifiable and are believed to be valid.

(1) The side on which the impact occurs in relation to the occupant seating position appears to be the most significant parameter in side-impact collisions.

(2) The number of inches of sheet metal crush and the overall occupant injury severity appear to be functions of the collision intensity.

(3) The side reinforcement beam appears to provide some benefit in terms of less sheet metal crush to the side structure of automobiles, but the measure of this benefit depends upon the make of automobile and the collision intensity. For General Motors Corporation automobiles, it appears to be beneficial only at the severe intensity levels. For Ford Motor Company automobiles, it appears to be beneficial at all intensity levels. For Chrysler Corporation automobiles, it appears to be of no added benefit at the moderate intensity levels, and no conclusion could be reached for the severe intensity levels.

(4) The side reinforcement beam appears, in general, to provide some benefit to occupants in terms of lower overall injury severity, but the measure of this benefit depends upon restraining belt usage and occupant seating position. For restrained occupants, it appears to be beneficial for all

seating positions. For unrestrained occupants, it appears to be beneficial to occupants sitting on the side of impact and detrimental to those sitting opposite the side of impact.

(5) The occupant restraining belts appear, in general, to provide some benefit to occupants in terms of lower overall injury severity, but the measure of this benefit depends upon the occupant seating position, the presence of side reinforcement beams, and the side of impact. For drivers, they appear to be beneficial in automobiles with side beam and in automobiles without side beam when the impact is on the driver's side, but detrimental in automobiles without side beam when the impact is on the opposite side. For right front passengers, they appear to be beneficial in automobiles without side beam, but detrimental in automobiles with side beam.

It must be remembered that conclusions 4 and 5 are based upon only the moderate intensity group.

CHAPTER V

RECOMMENDATIONS

The collision intensity parameter and the methodology established for its application have proven to be invaluable in the analysis of this subset of accident data. This approach was developed for the analysis of side-impact accident data, but it should be equally powerful in the analysis of accident data in general, regardless of the type of collision or the types of objects involved.

Therefore, based upon the results obtained from this analysis, the following recommendations are made.

(1) This study should be expanded to include a much larger number of cases so that sufficient data would be available for all of the categories for all of the collision intensity levels. The side impact set of accidents used for this study included a total of 906 vehicles, but, as a result of the various classifications and restrictions, was reduced to a usable number of 172 U. S. manufactured automobiles.

(2) The MDAI File should be restructured using the concept of a 'striking vehicle' and a 'struck vehicle'. This concept is based on the premise that two vehicles cannot occupy the same space at the same time. Under this concept,

the vehicle that first occupied a given space would be the 'struck vehicle'. The vehicle that penetrated that space would be the 'striking vehicle'. In the event that they arrived at approximately the same time, each vehicle would be a 'striking vehicle'. This determination can be easily made using the following procedure:

(a) if one of the vehicles could be stopped just prior to impact and the collision still occurred, then the stopped vehicle is a 'struck vehicle';

(b) if one of the vehicles could be stopped just prior to impact and the collision did not occur, then the stopped vehicle is a 'striking vehicle';

(c) if either of the vehicles could be stopped just prior to impact and the collision still occurred, then each of the vehicles is a 'striking vehicle'.

(3) The Collision Performance and Injury Report (Revision 3) should be modified so that the vehicle kinematics for all vehicles involved in an accident can be reported. This recommendation is not intended to infer that all data elements should be collected for all vehicles in an accident because it is recognized that some models or types of vehicles may be of more current interest than others. However, the kinematics for all vehicles is necessary in order for the accident to be properly categorized by a collision intensity parameter.

(4) The vehicle make/model code and the vehicle body

style code should be combined into a single vehicle model identification code. The vehicle make/model code is data elements V113-V118 for the 'Case Vehicle' and V83-V88 for the 'Other Vehicle', and the body style code is data element V124 for the 'Case Vehicle' and V94 for the 'Other Vehicle'. Using the present scheme, station wagons cannot be separated from sedans using the make/model code and from pickup cars using the body style code, but pickup cars can be identified by the make/model code. Therefore, station wagons can be identified only by the process of elimination. It is necessary to be able to identify station wagons because of their differences in body structure, in handling characteristics, and in their sensitivity to weight and tire pressure distributions. In addition, trucks are identifiable by both codes, whereas trains and buses are identifiable by the make/model code but not by the body style code.

(5) A standard vehicle weight code should be established to categorize similar models of different manufacture. The vehicle weights listed in the MDAI File include a different weight for each body style for each year for each model for each manufacturer. The actual vehicle weights will depend upon such factors as optional equipment, engine size, and number of occupants as well as vehicle body style, model, and manufacturer. However, since the significance of the collision intensity parameter lies in its relative value rather than its absolute value, a standardized vehicle weight

could be used without affecting its significance.

(6) The values for the equivalent resiliency coefficient should be established so that the collision intensity parameter can be applied to other than automobile-to-automobile collisions. The MDAI File includes a series of 32 objects that may be contacted and lists as many as four that were contacted by each 'Case Vehicle' in an accident. The intensity of each collision will depend upon the degree of energy absorption and/or deformation of each object in the collision. This coefficient would then make possible the comparison of accident data from different types of accidents and from different collisions in a multiple collision accident.

APPENDICES

APPENDIX A

COLLISION CONFIGURATIONS

Table A-1 gives the orientation angles for each of the combinations of o'clock directions of principle force for the 'Case Vehicle' and 'Other Vehicle', respectively.

Figures A-1 through A-12 give the collision configurations that are possible for each of the combinations of o'clock directions of principle force for each of the vehicles. The vehicles are displayed in a typical configuration, however, the exact configuration may vary slightly so long as the relationship between the opposing principle forces and orientation angles remains unchanged. The following notes pertain to the figures:

(1) the numbers above each figure are the o'clock directions of principle forces for the 'Case Vehicle' and 'Other Vehicle', respectively;

(2) the closed arrows represent the principle forces acting on each vehicle and point toward the vehicle on which they act;

(3) the open arrows represent the primary direction of travel and point toward the front of each vehicle;

(4) the angles indicated are the orientation angles for each vehicle.

Table A-1. Orientation Angles for Collision Configurations

OV	12		01		02		03		04		05		06		07		08		09		10		11		
CV	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	θ_1	θ_2	
12	0	0	0	30	0	60	0	90	0	120	0	150	0	180	0	-150	0	-120	0	-90	0	-60	0	-30	12
01	30	0	30	30	30	60	30	90	30	120	30	150	30	180	30	-150	30	-120	30	-90	30	-60	30	-30	01
02	60	0	60	30	60	60	60	90	60	120	60	150	60	180	60	-150	60	-120	60	-90	60	-60	60	-30	02
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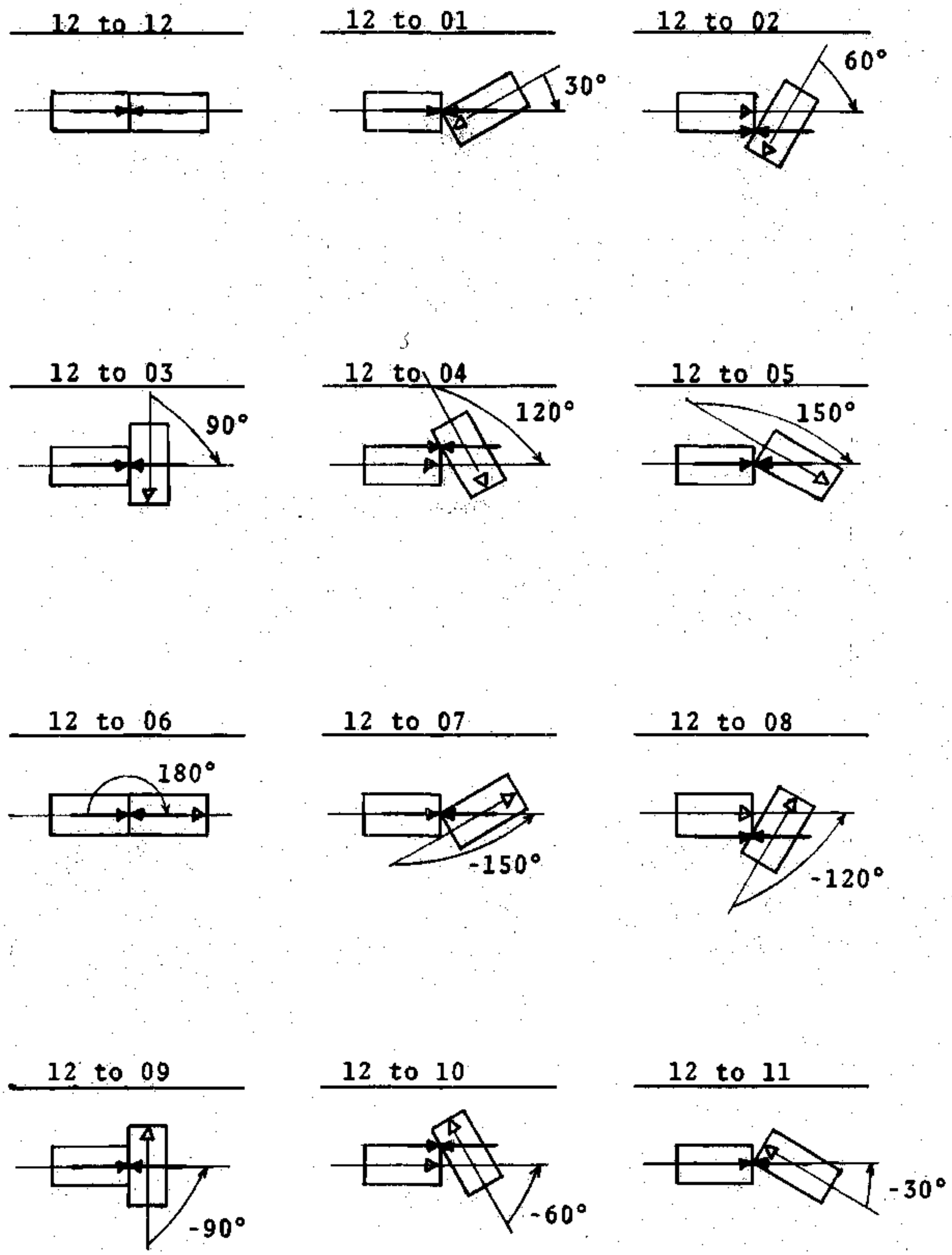
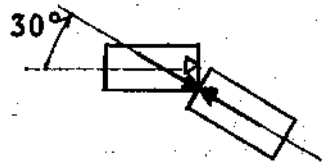
θ_1 = Case Vehicle θ_2 = Other Vehicle


12 to 12
12 to 01
30°
12 to 02
60°
12 to 03
90°
12 to 04
120°
12 to 05
150°
12 to 06
180°
12 to 07
-150°
12 to 08
-120°
12 to 09
-90°
12 to 10
-60°
12 to 11
-30°

01 to 12



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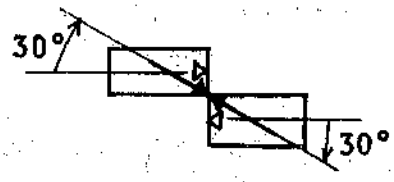

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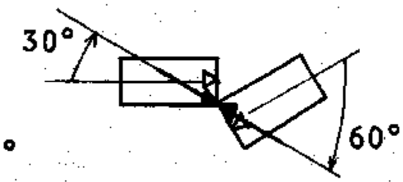

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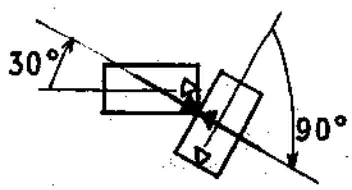

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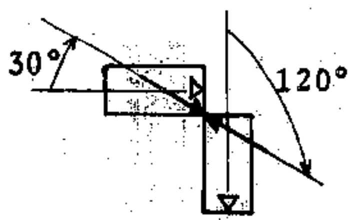

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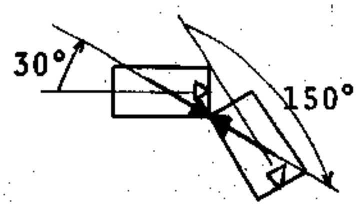

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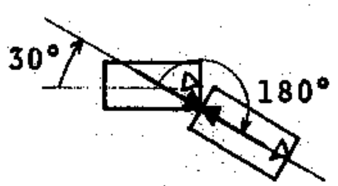

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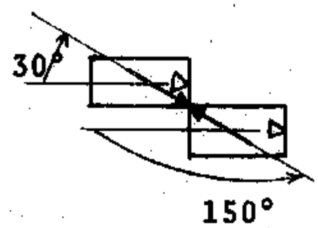

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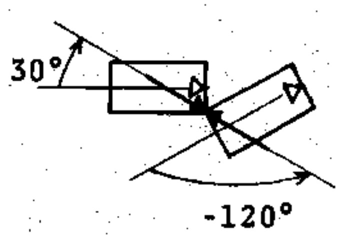

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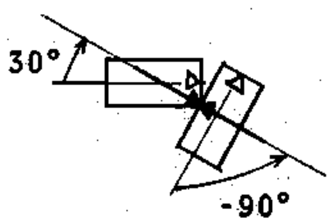

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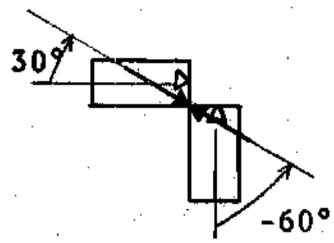

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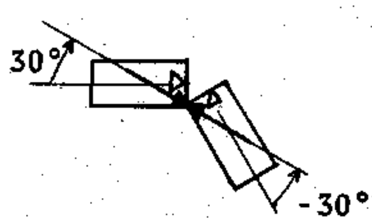

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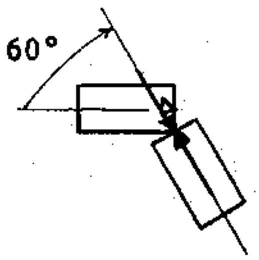

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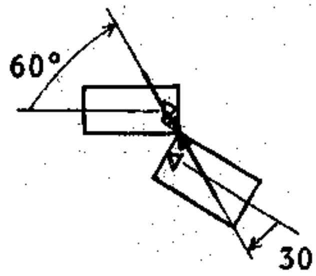

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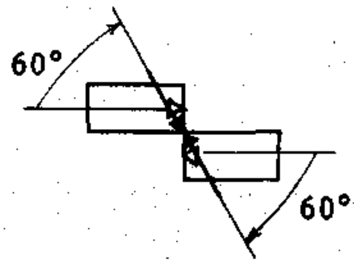

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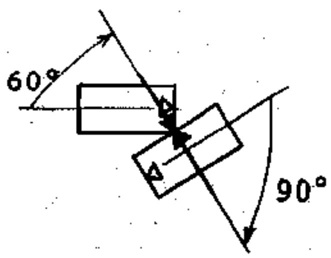

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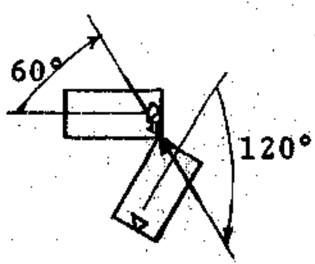

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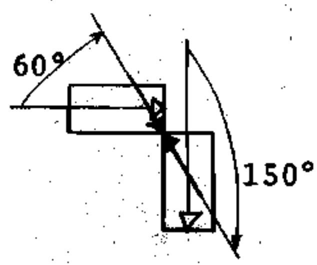

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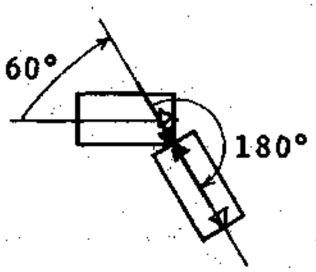

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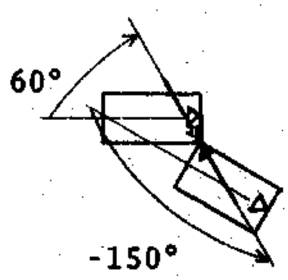

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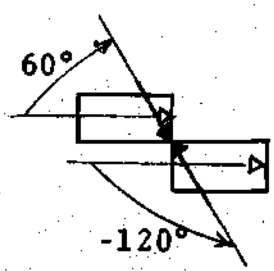

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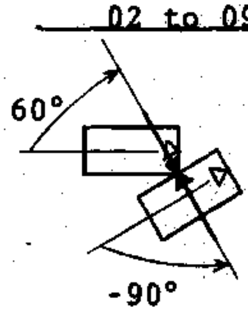

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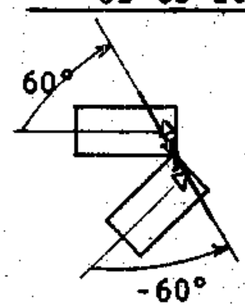

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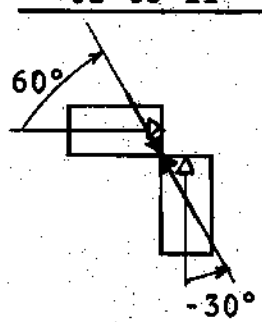

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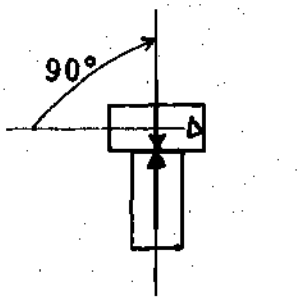

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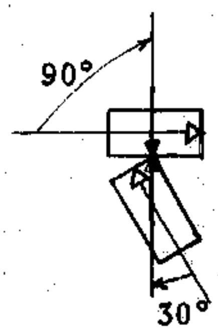

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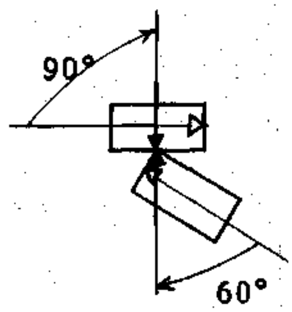

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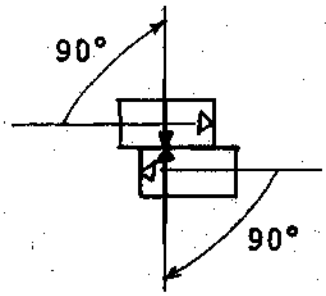

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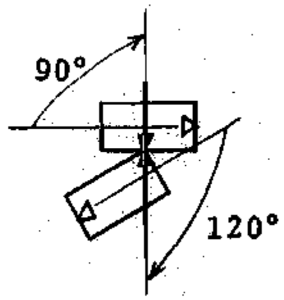

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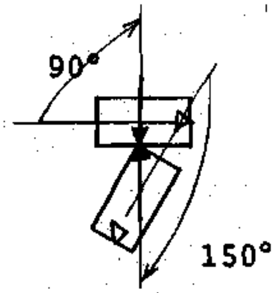

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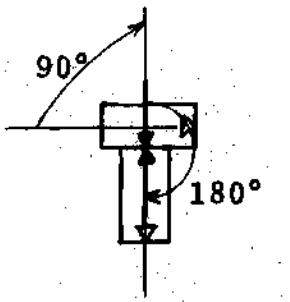

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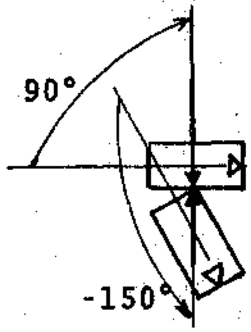

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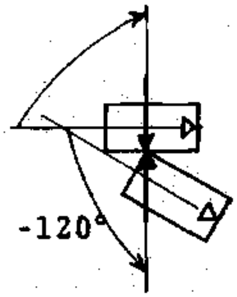

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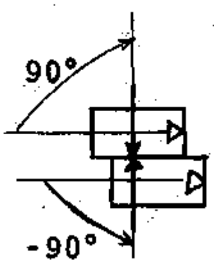

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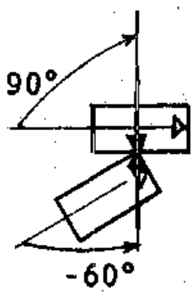

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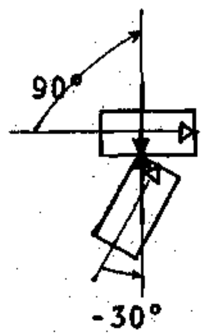

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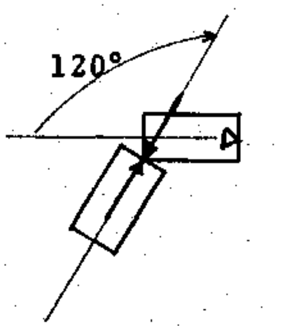

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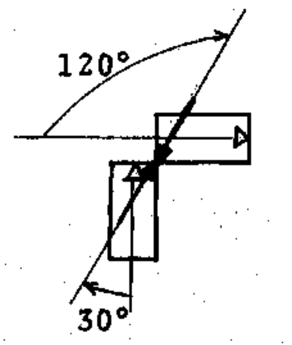

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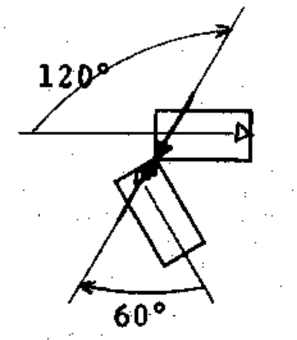

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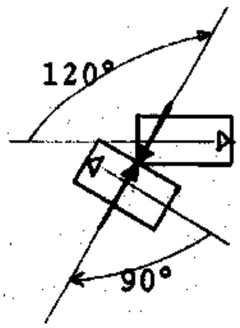

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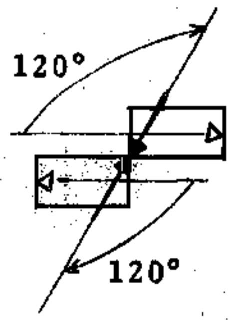

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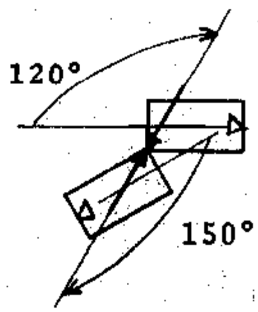

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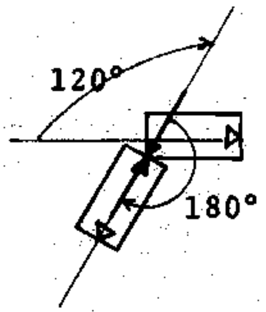

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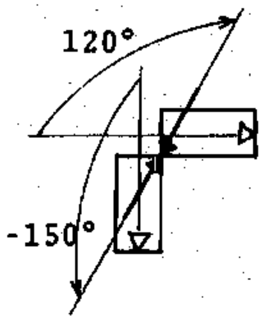

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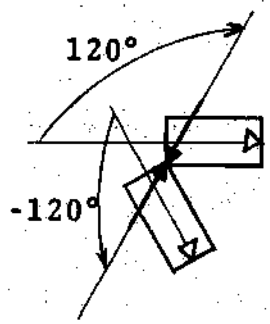

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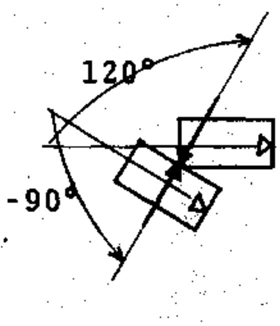

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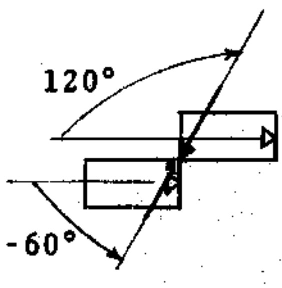

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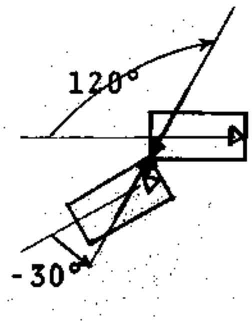

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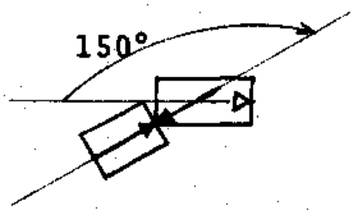

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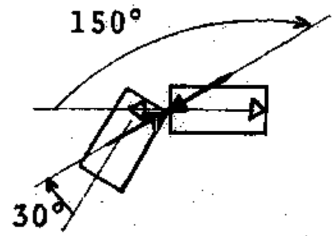

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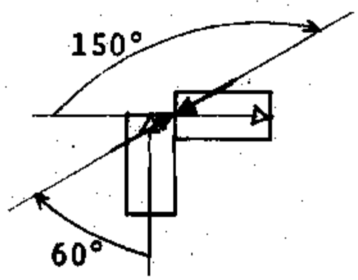

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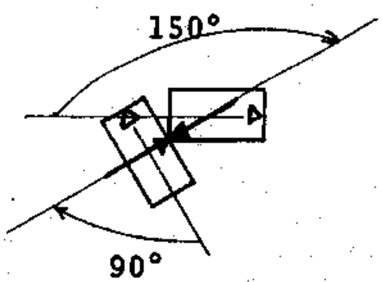

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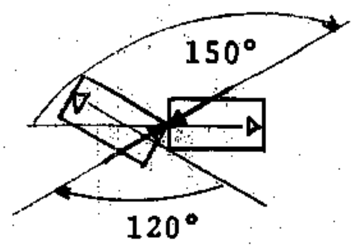

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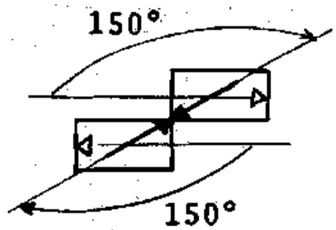

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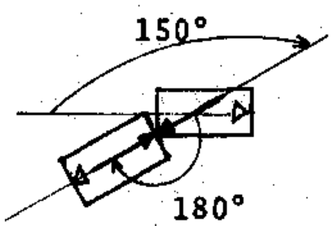

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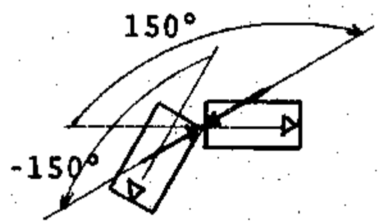

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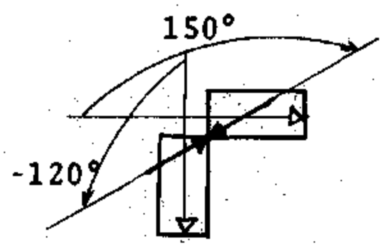

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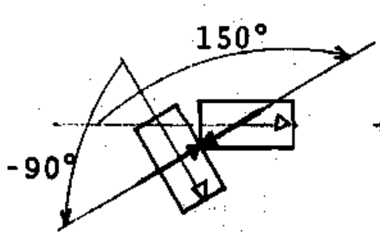

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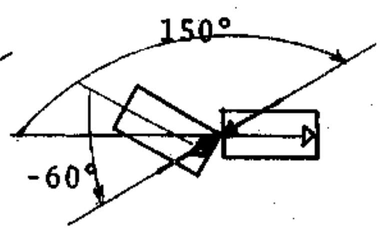

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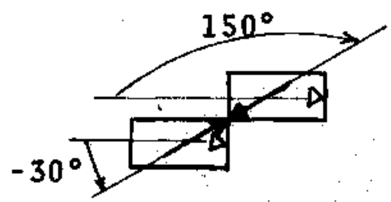

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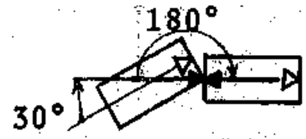

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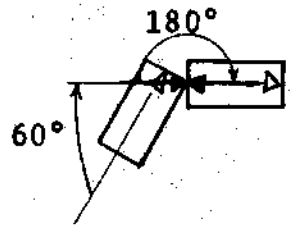

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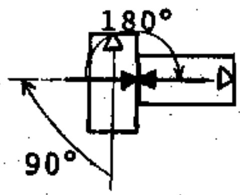

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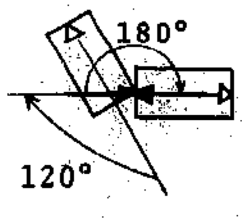

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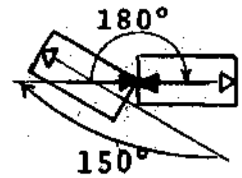

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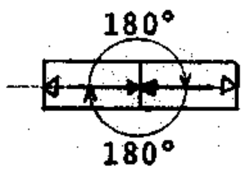

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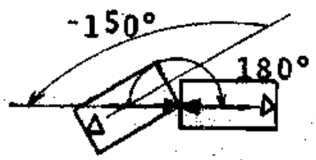

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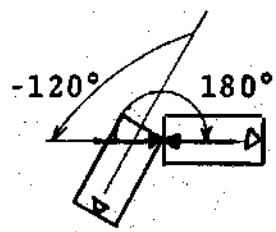

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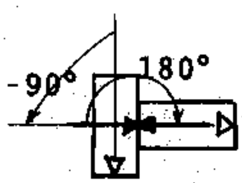

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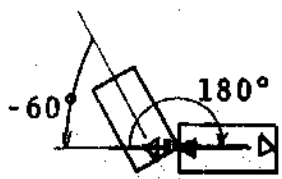

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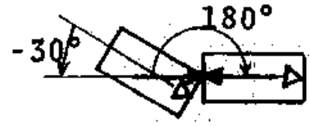

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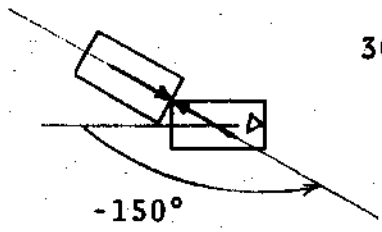

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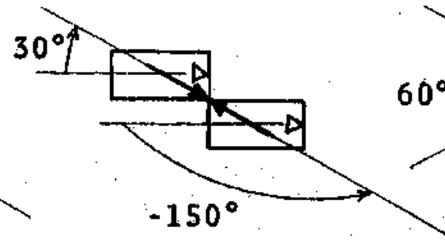

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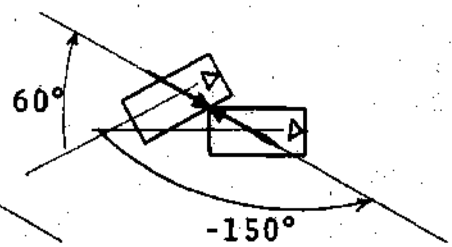

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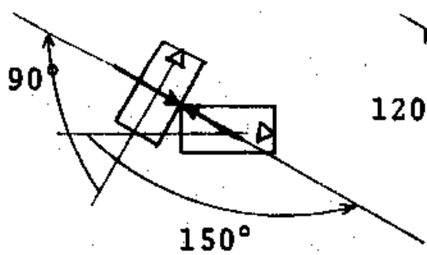

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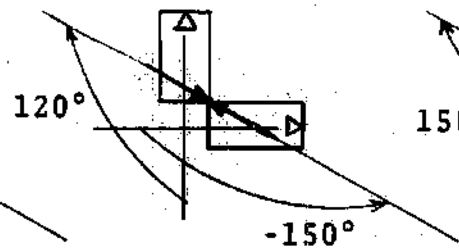

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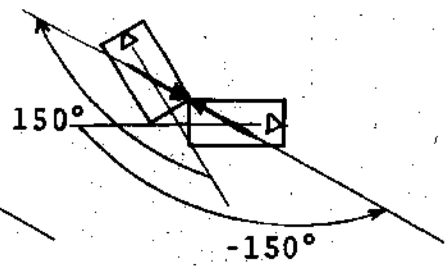

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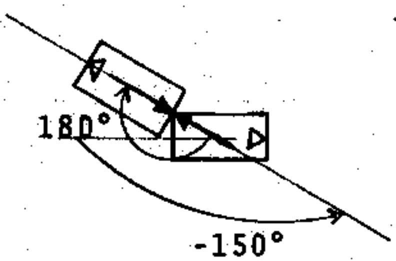

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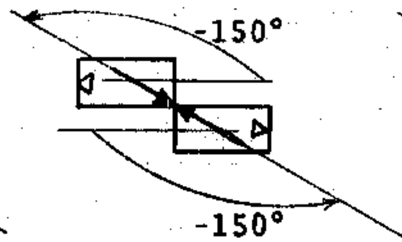

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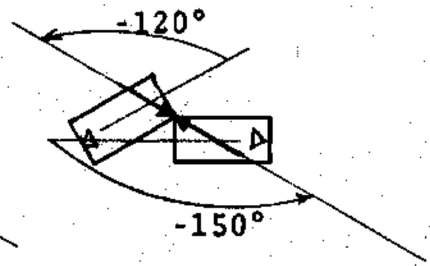

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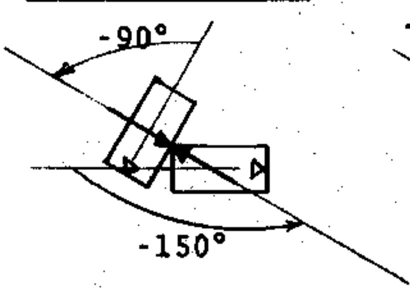

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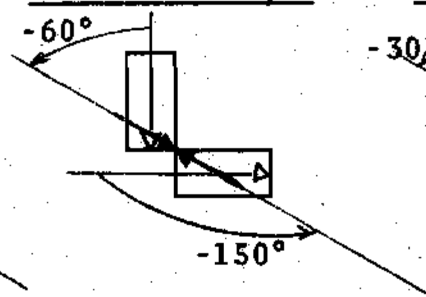

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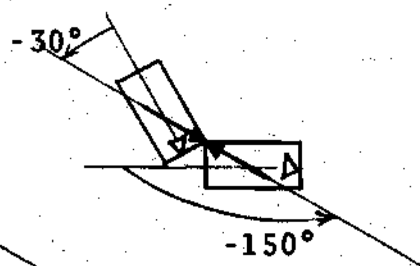

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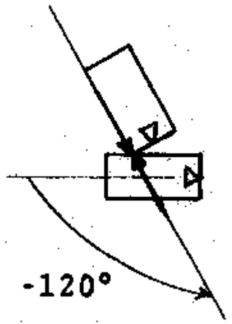

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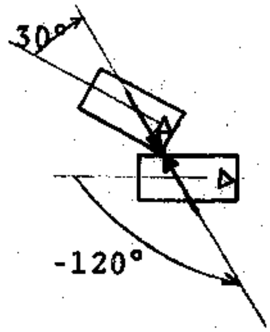

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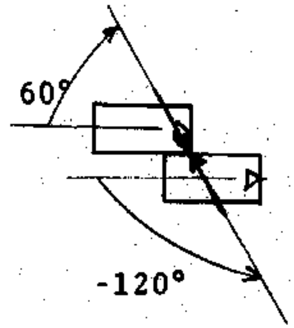

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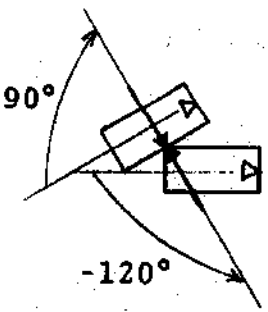

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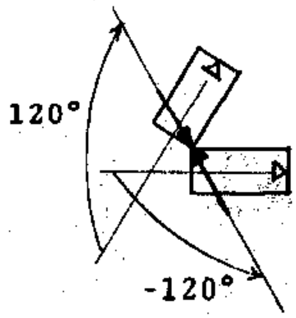

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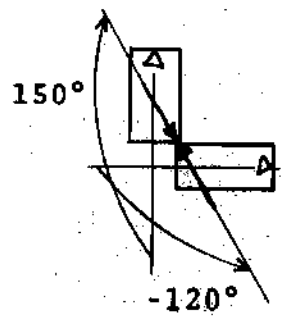

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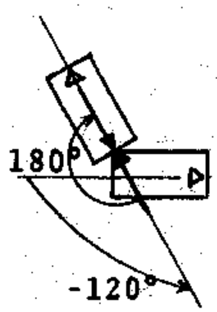

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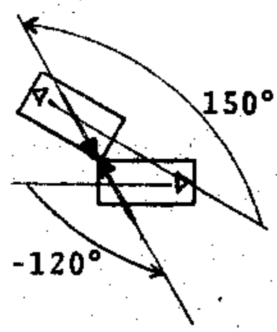

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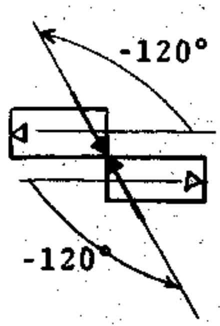

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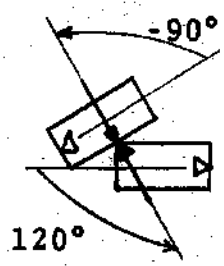

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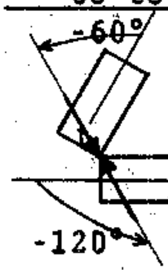

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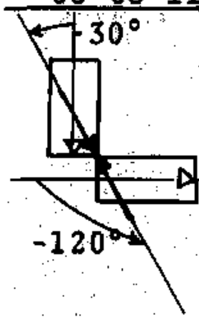

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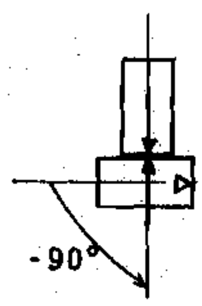

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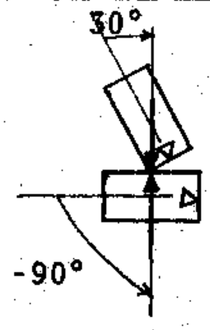

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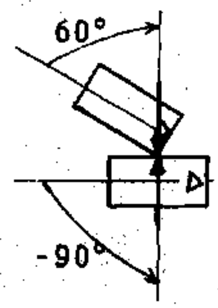

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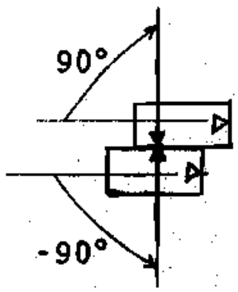

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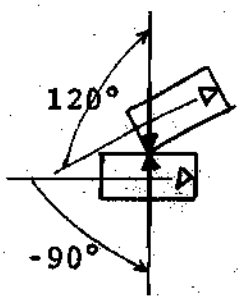

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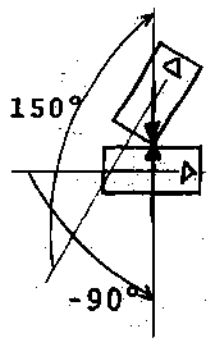

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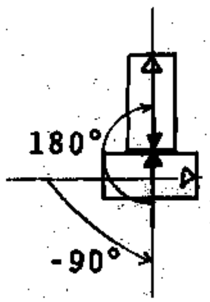

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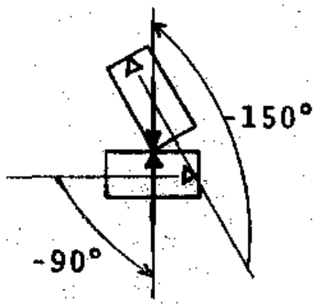

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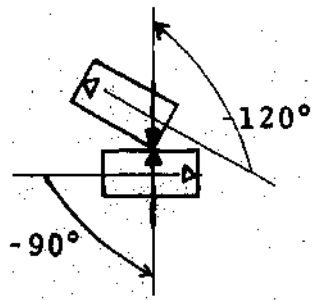

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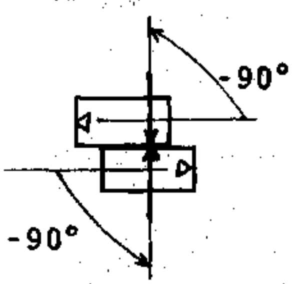

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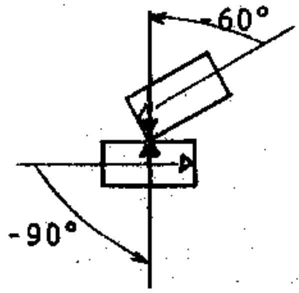

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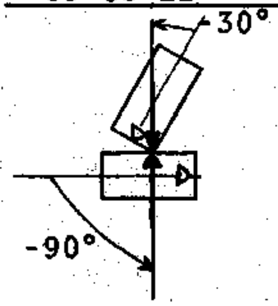

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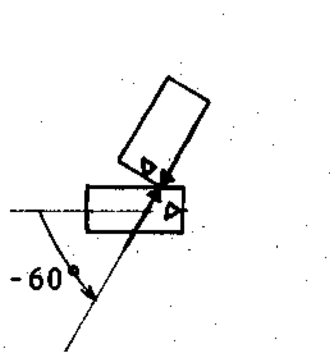

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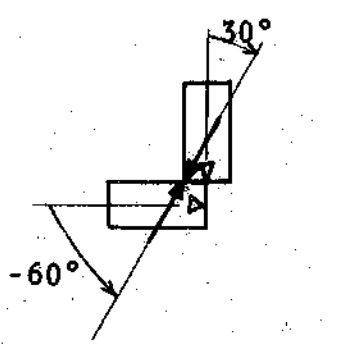

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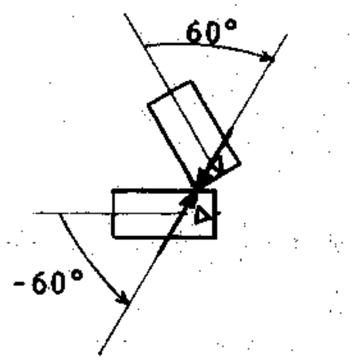

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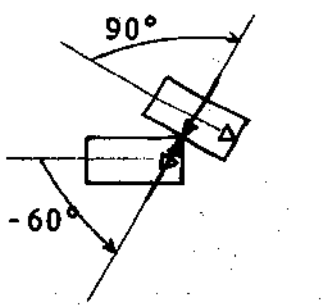

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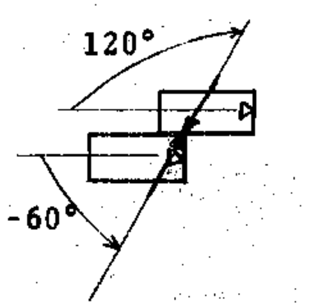

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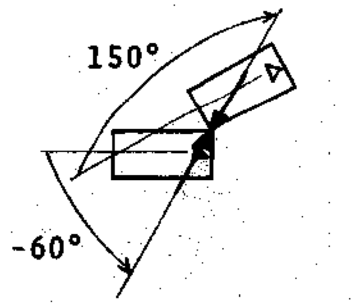

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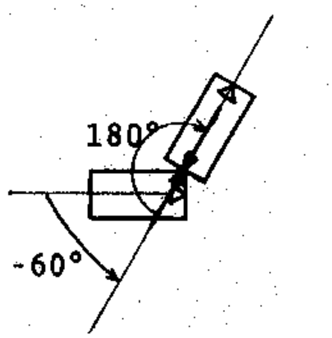

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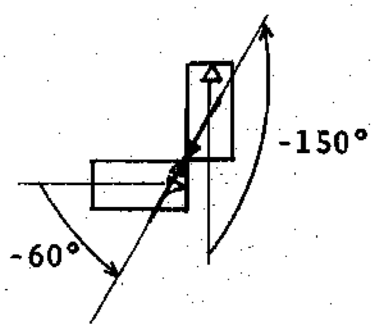

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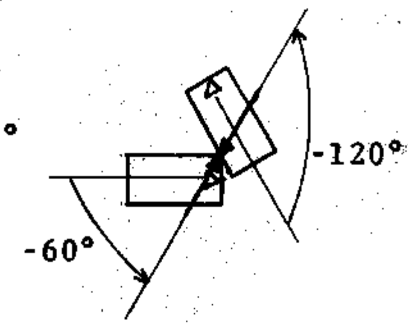

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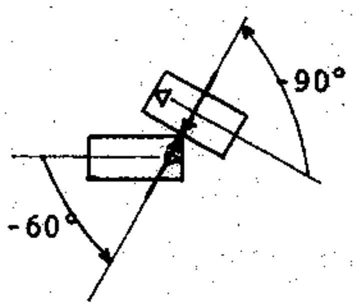

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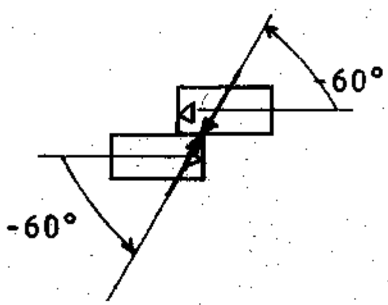

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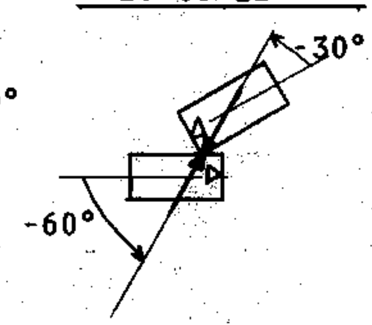

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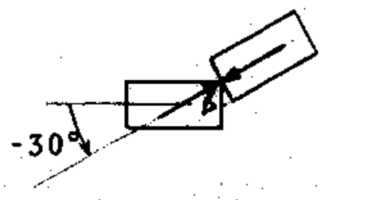

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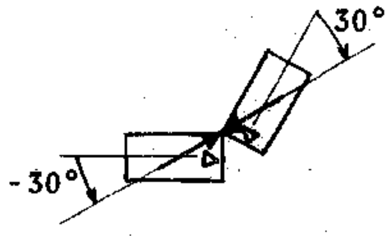

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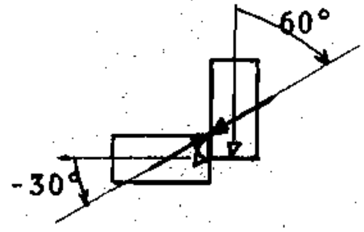

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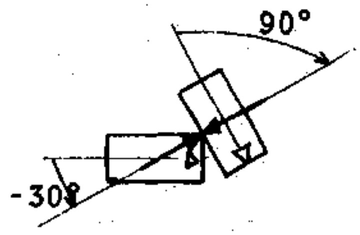

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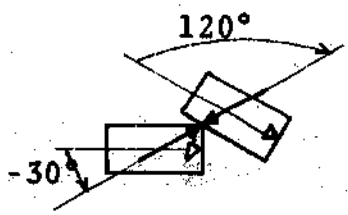

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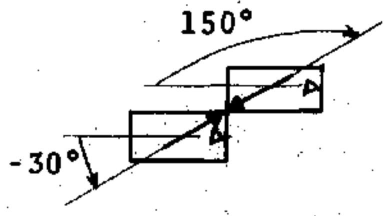

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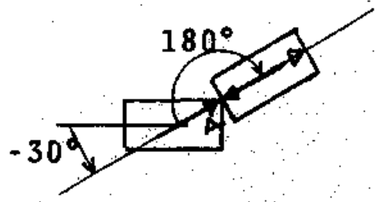

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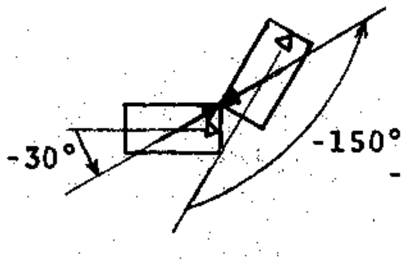

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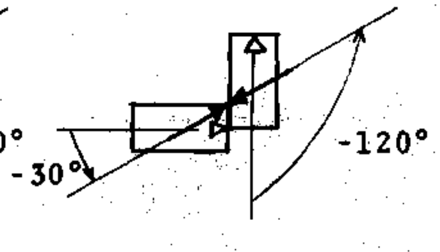

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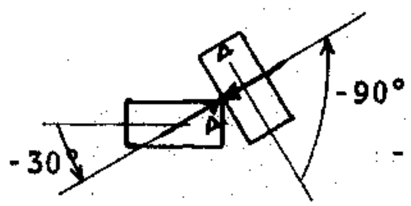

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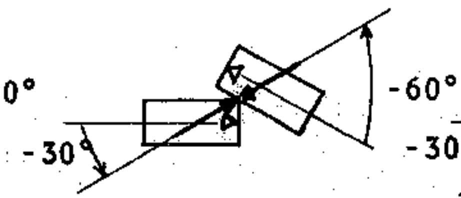

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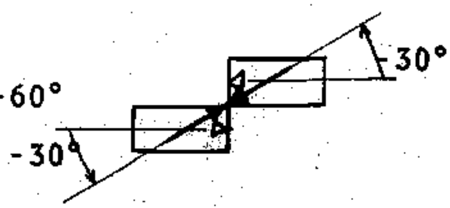


APPENDIX B

SAMPLE CALCULATION OF COLLISION INTENSITY PARAMETER

Case No.: GIT 260 102
Type Collision: Automobile-to-Automobile

CV = 11301	OV = 61809
M_1 = 3700 lbs	M_2 = 1700 lbs
v_1 = 10 mph	v_2 = 25 mph
CDC_1 = 10 LYEW2	CDC_2 = 01FDEW4
θ_1 = 300°	θ_2 = 30°
A = 1.0	

$$CI = A[M_1 v_1 \cos\ _1 + M_2 v_2 \cos\theta_2]$$

$$= (1.0)[(3700)(10)(.50) + (1700)(25)(.867)]$$

$$CI = 55.3 \times 10^3 \text{ lb-mi/hr}$$

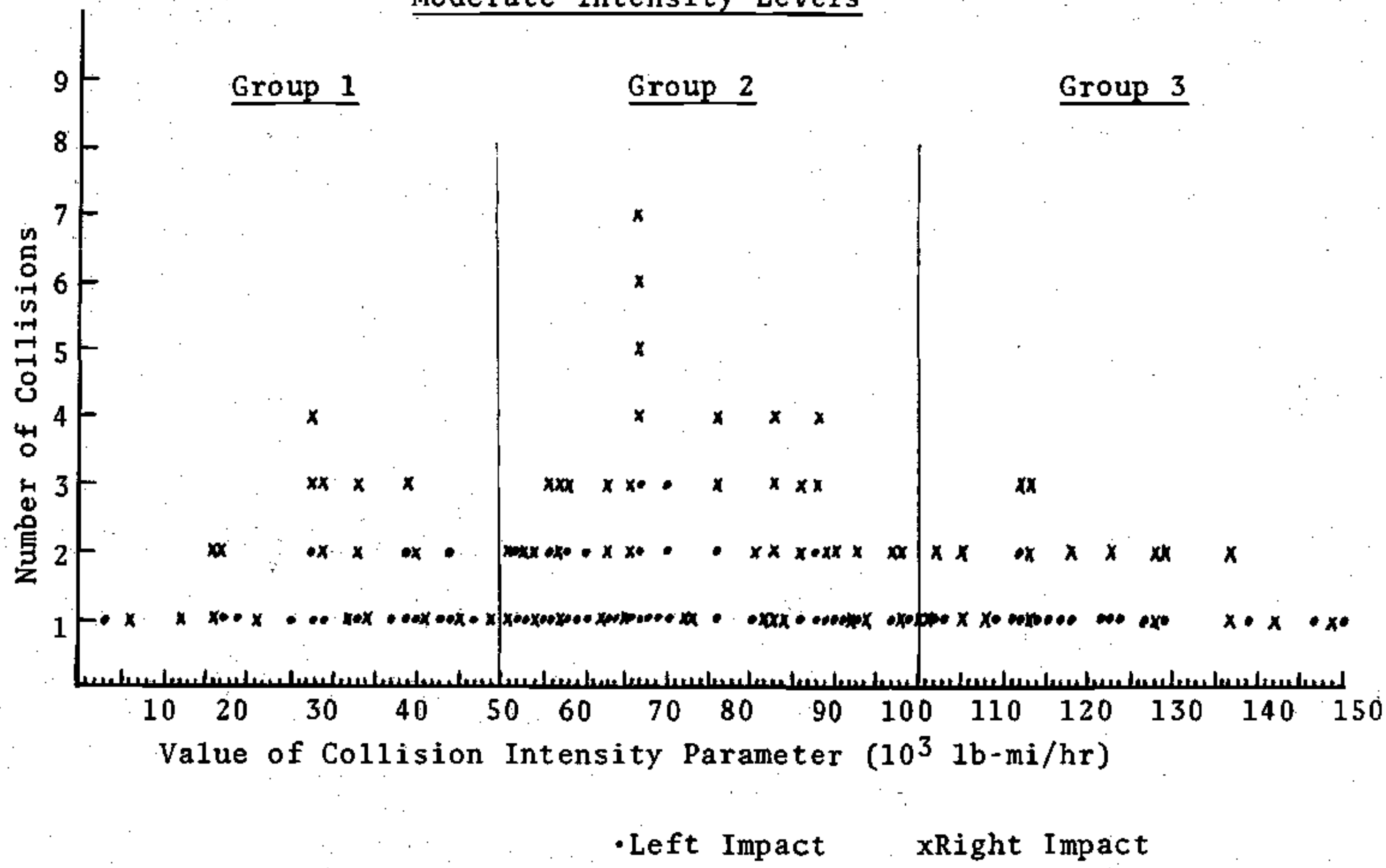
The units of the collision intensity parameter are expressed as 10^3 lb-mi/hr. They were not converted to conventional momentum units, slugs-ft/sec, because the significance of the parameter lies in its relative value rather than its absolute value.

APPENDIX C

DISTRIBUTION OF VALUES FOR COLLISION INTENSITY PARAMETER

Automobile-to-Automobile Subset

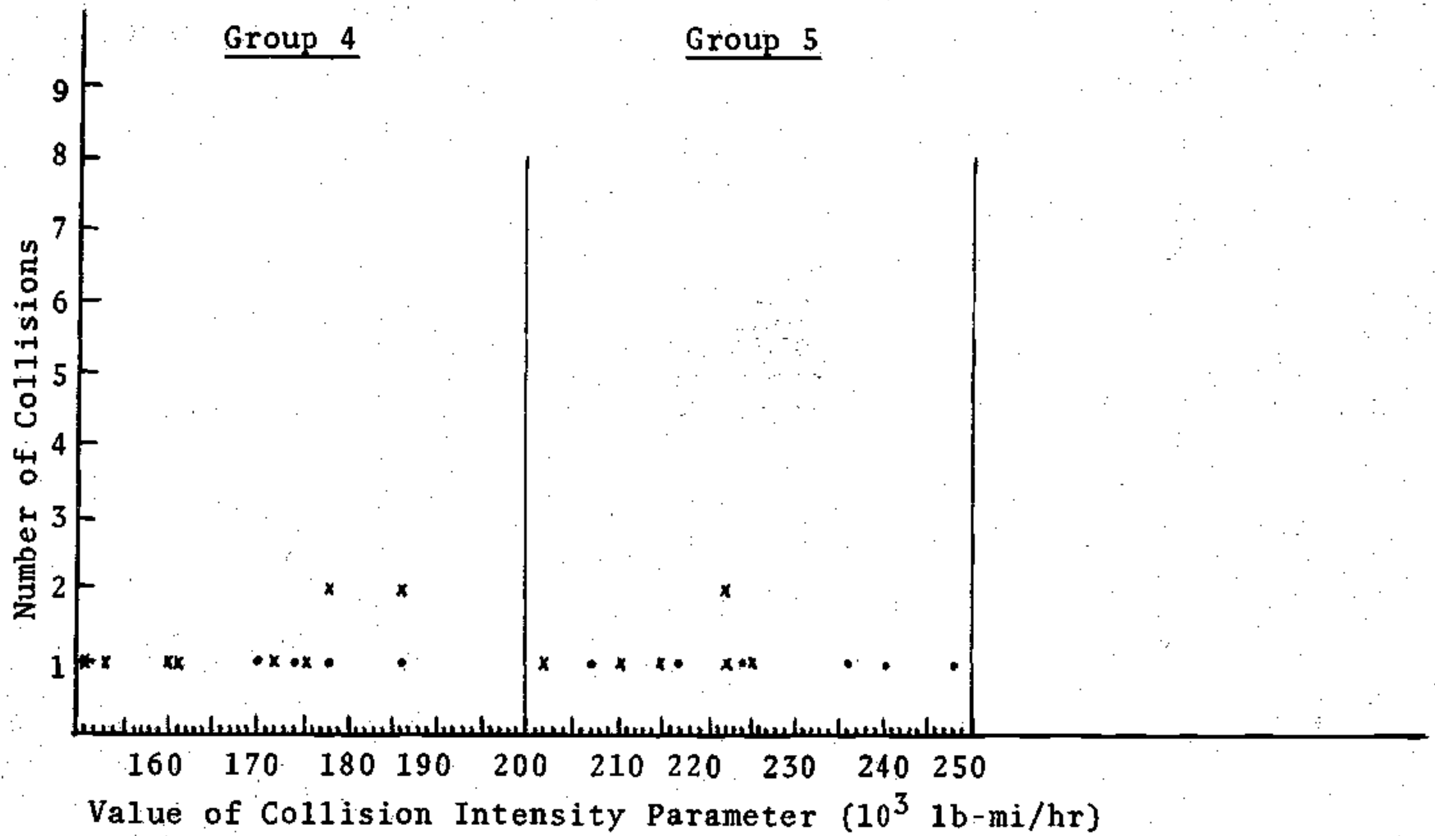
Moderate Intensity Levels



DISTRIBUTION OF VALUES FOR COLLISION INTENSITY PARAMETER

Automobile-to-Automobile Subset

Severe Intensity Levels



•Left Impact xRight Impact

APPENDIX D

MODEL YEAR OF INTRODUCTION OF SIDE REINFORCEMENT BEAMS BY AUTOMOBILE MANUFACTURER

Corporation	Year of Introduction				
	1969	1970	1971	1972	1973
General Motors	11102 11103 11203 11204 11302 11402 11403 11502	11101 11301 11306 11401 11501 11506 11507	11105 11205 11318 11405		All Remaining Models
Chrysler		13206 13406			All Remaining Models
Ford			12102 12106 12202 12203 12206		All Remaining Models
American Motors			14106		All Remaining Models

APPENDIX E

Table E-1. Summary of Number of 'Case Vehicles' in the Automobile-to-Automobile Subset of Side-Impact Collisions

Parameter		With Side Beam			Without Side Beam			Total
		Left Impact	Right Impact	Total	Left Impact	Right Impact	Total	
Moderate	GM	15	27	42	14	14	28	70
	Ford	1	5	6	27	15	42	48
	Chrysler	1	2	3	9	18	27	30
Severe	GM	4	3	7	2	6	8	15
	Ford	1		1	3	2	5	6
	Chrysler					3	3	3
Moderate		17	34	51	50	47	97	148
Severe		5	3	8	5	11	16	24
Total		22	37	59	55	58	113	172

APPENDIX F

Table F-1. Average Value for Damage Extent Zone by With and Without Side Beam and Automobile Manufacturer

Collision Intensity Group		With Side Beam		Without Side Beam		Total	
		No. Autos	Avg. Zone	No. Autos	Avg. Zone	No. Autos	Avg. Zone
1	GM	8	2.38	7	2.72	15	2.54
	Ford	1	3.00	16	2.50	17	2.53
	Chrysler			3	3.00	3	3.00
	All	9	2.44	26	2.62	35	2.57
2	GM	23	2.78	16	2.69	39	2.74
	Ford	2	2.00	18	3.06	20	2.95
	Chrysler	1	3.00	17	2.70	18	2.72
	All	26	2.73	51	2.82	77	2.79
3	GM	11	3.27	5	3.20	16	3.25
	Ford	3	2.67	8	3.88	11	3.54
	Chrysler	2	1.50	7	3.14	9	2.78
	All	16	2.94	20	3.45	36	3.22
4	GM	2	3.00	4	3.75	6	3.50
	Ford	1	2.00	3	3.00	4	2.75
	Chrysler			2	3.50	2	3.50
	All	3	2.67	9	3.44	12	3.25
5	GM	5	4.00	4	3.75	9	3.89
	Ford			2	6.00	2	6.00
	Chrysler			1	5.00	1	5.00
	All	5	4.00	7	4.57	12	4.33

APPENDIX G

Table G-1. Summary of Number of Occupants in the 'Case Vehicles' in the Automobile-to-Automobile Subset of Side-Impact Collisions

Parameter		With			Without			Total
		Left	Right	Total	Left	Right	Total	
Moderate	R	4	8	12	19	10	29	41
	U	23	53	76	68	69	137	213
Severe	R	8	1	9	0	8	8	17
	U	3	5	8	7	11	18	26
Restrained		12	9	21	19	18	37	58
Unrestrained		26	58	84	75	80	155	239
Moderate		27	61	88	87	79	166	254
Severe		11	6	17	7	19	26	43
Total		38	67	105	94	98	192	297
Restraint Unknown Moderate		3	1	4	5	2	7	11
Injury Unknown Moderate		0	0	0	3	2	5	5
Grand Total		41	68	109	102	102	204	313

APPENDIX H

Table H-1. Number of Types of Injuries per Occupant by Side of Impact and With and Without Side Beam
Moderate Intensity
Restrained Drivers

Type	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
None, Unknown		.50		.11
Fracture	.33		.27	
Laceration	.67	.25	.27	.67
Contusion	.67	1.00	1.64	.67
Complaint of Pain	1.33	.50	1.00	1.45
Abrasion		.25	.45	.22
Concussion			.09	
Burn				
Hemorrhage				
Other			.18	.11
Total	3.00	2.50	3.91	3.22
No. Occupants	3	4	11	9

Restrained: 19% of MI Group Drivers

With: 26% of Restrained MI Group Drivers

Without: 74% of Restrained MI Group Drivers

Table H-2. Number of Types of Injuries per Occupant by Side of Impact and With and Without Side Beam

Moderate Intensity
Unrestrained Drivers

Type	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
None, Unknown	.14	.17	.11	.25
Fracture	.21	.17	.50	.08
Laceration	.57	.73	.50	.56
Contusion	1.00	1.03	1.28	.61
Complaint of Pain	1.07	1.03	.69	.53
Abrasion		.47	.39	.33
Concussion	.07	.10	.14	.11
Burn			.03	
Hemorrhage			.17	.03
Other	.29	.27	.22	.03
Total	3.36	3.97	4.03	2.53
No. Occupants	14	30	36	36

Unrestrained: 81% of MI Group Drivers

With: 38% of Unrestrained MI Group Drivers

Without: 62% of Unrestrained MI Group Drivers

Table H-3. Number of Types of Injuries per Occupant by Side of Impact and With and Without Side Beam

Moderate Intensity
Restrained Right Front Passengers

Type	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
None, Unknown			.40	
Fracture		.67		
Laceration	1.00	.67	.20	1.00
Contusion	1.00	3.33	.60	
Complaint of Pain	1.00	3.00		1.00
Abrasion		.33		
Concussion		.33		
Burn				
Hemorrhage		.33		
Other		.33		
Total	3.00	9.00	1.20	2.00
No. Occupants	1	3	5	1

Restrained: 15% of MI Group Right Front Passengers

With: 40% of Restrained MI Group RFP

Without: 60% of Restrained MI Group RFP

Table H-4. Number of Types of Injuries per Occupant by Side of Impact and With and Without Side Beam

Moderate Intensity
Unrestrained Right Front Passengers

Type	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
None, Unknown			.19	.10
Fracture		.25	.19	.15
Laceration	.43	.42	.44	.80
Contusion	.86	.92	1.06	.75
Complaint of Pain	.43	.83	.38	.35
Abrasion	.43	.42	.55	.30
Concussion		.17	.13	.10
Burn				
Hemorrhage	.14		.06	.15
Other	.14	.17	.13	.30
Total	2.43	3.17	3.12	3.00
No. Occupants	7	12	16	20

Unrestrained: 85% of MI Group Right Front Passengers

With: 35% of Unrestrained MI Group RFP

Without: 65% of Unrestrained MI Group RFP

Table H-5. Number of Types of Injuries per Occupant by Side of Impact and With and Without Side Beam

Severe Intensity
Restrained Drivers

Type	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
None, Unknown				
Fracture		1.00		1.20
Laceration	1.00	1.00		2.20
Contusion	2.00			2.40
Complaint of Pain	1.50			
Abrasion	.25			2.40
Concussion	.25			
Burn				
Hemorrhage		1.00		.40
Other	.75	1.00		
Total	5.75	4.00		8.60
No. Occupants	4	1		5

Restrained: 42% of SI Group Drivers

With: 50% of Restrained SI Group Drivers

Without: 50% of Restrained SI Group Drivers

Table H-6. Number of Types of Injuries per Occupant by Side of Impact and With and Without Side Beam

Severe Intensity
Unrestrained Drivers

Type	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
None, Unknown				.17
Fracture	1.00	.50	.80	.83
Laceration	1.00	1.50	2.20	.50
Contusion	2.00	1.00	2.00	.83
Complaint of Pain	3.00		.20	
Abrasion			1.20	
Concussion			.20	.17
Burn				
Hemorrhage			.60	.33
Other			.20	.17
Total	7.00	3.00	7.40	3.00
No. Occupants	1	2	5	6

Unrestrained: 58% of SI Group Drivers

With: 21% of Unrestrained SI Group Drivers

Without: 79% of Unrestrained SI Group Drivers

Table H-7. Number of Types of Injuries per Occupant by Side of Impact and With and Without Side Beam

Severe Intensity
Restrained Right Front Passengers

Type	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
None, Unknown				
Fracture				3.50
Laceration				3.50
Contusion				3.50
Complaint of Pain				
Abrasion				1.50
Concussion				
Burn				
Hemorrhage				.50
Other				
Total				12.50
No. Occupants				2

Restrained: 20% of SI Group Right Front Passengers

Table H-8. Number of Types of Injuries per Occupant by Side of Impact and With and Without Side Beam

Severe Intensity
Unrestrained Right Front Passengers

Type	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
None, Unknown				
Fracture		2.00	1.00	1.67
Laceration	.50			.67
Contusion		.50		1.00
Complaint of Pain	2.50			
Abrasion		.50	1.00	1.00
Concussion		.50		
Burn				
Hemorrhage		.50		.67
Other			1.00	1.33
Total	3.00	4.00	3.00	6.33
No. Occupants	2	2	1	3

Unrestrained: 80% of SI Group Right Front Passengers

With: 50% of Unrestrained SI Group RFP

Without: 50% of Unrestrained SI Group RFP

APPENDIX I

Table I-1. Average Value of Occupant A.I.S. by Seat Position and Location and by Automobile Manufacturer

Severe Intensity
Restrained Occupants
With Side Beam
Left Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	3	1.33	1	0.00			4	1.00
	Ford	1	1.00					1	1.00
	Chrysler								
	All	4	1.25	1	0.00			5	1.00
Rear	GM	1	7.00	1	2.00	1	0.00	3	3.00
	Ford								
	Chrysler								
	All	1	7.00	1	2.00	1	0.00	3	3.00
Total	GM	4	2.75	2	1.00	1	0.00	7	1.86
	Ford	1	1.00					1	1.00
	Chrysler								
	All	5	2.40	2	1.00	1	0.00	8	1.75

Table I-2. Average Value of Occupant A.I.S. by Seat Position and Location and by Automobile Manufacturer

Severe Intensity
Restrained Occupants
With Side Beam
Right Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	1	3.00					1	3.00
	Ford								
	Chrysler								
	All	1	3.00					1	3.00
Rear	GM								
	Ford								
	Chrysler								
	All								
Total	GM	1	3.00					1	3.00
	Ford								
	Chrysler								
	All	1	3.00					1	3.00

Table I-3. Average Value of Occupant A.I.S. by Seat Position and Location and by Automobile Manufacturer

Severe Intensity
Restrained Occupants
Without Side Beam
Left Impact

No cases in this category

Table I-4. Average Value of Occupant A.I.S. by Seat Position and Location and by Automobile Manufacturer

Severe Intensity
Restrained Occupants
Without Side Beam
Right Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	3	8.00			1	9.00	4	8.25
	Ford			1	0.00			1	0.00
	Chrysler	2	2.50			1	6.00	3	3.67
	All	5	5.80	1	0.00	2	7.50	8	5.50
Rear	GM								
	Ford								
	Chrysler								
	All								
Total	GM	3	8.00			1	9.00	4	8.25
	Ford			1	0.00			1	0.00
	Chrysler	2	2.50			1	6.00	3	3.67
	All	5	5.80	1	0.00	2	7.50	8	5.50

Table I-5. Average Value of Occupant A.I.S. by Seat Position and Location and by Automobile Manufacturer

Severe Intensity
Unrestrained Occupants
With Side Beams
Left Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	1	2.00			2	1.50	3	1.67
	Ford								
	Chrysler								
	All	1	2.00			2	1.50	3	1.67
Rear	GM								
	Ford								
	Chrysler								
	All								
Total	GM	1	2.00			2	1.50	3	1.67
	Ford								
	Chrysler								
	All	1	2.00			2	1.50	3	1.67

Table I-6. Average Value of Occupant A.I.S. by Seat Position and Location and by Automobile Manufacturer

Severe Intensity
Unrestrained Occupants
With Side Beams
Right Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	2	1.50			2	3.00	4	2.25
	Ford								
	Chrysler								
	All	2	1.50			2	3.00	4	2.25
Rear	GM			1	1.00				
	Ford								
	Chrysler								
	All			1	1.00				
Total	GM	2	1.50	1	1.00	2	3.00	5	2.00
	Ford								
	Chrysler								
	All	2	1.50	1	1.00	2	3.00	5	2.00

Table I-7. Average Value of Occupant A.I.S. by Seat Position and Location and by Automobile Manufacturer

Severe Intensity
Unrestrained Occupants
Without Side Beams
Left Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	2	5.50					2	5.50
	Ford	3	3.00			1	6.00	4	3.75
	Chrysler								
	All	5	4.00			1	6.00	6	4.33
Rear	GM								
	Ford					1	3.00	1	3.00
	Chrysler								
	All					1	3.00	1	3.00
Total	GM	2	5.50					2	5.50
	Ford	3	3.00			2	4.50	5	3.60
	Chrysler								
	All	5	4.00			2	4.50	7	4.14

Table I-8. Average Value of Occupant A.I.S. by Seat Position and Location and by Automobile Manufacturer

Severe Intensity
Unrestrained Occupants
Without Side Beams
Right Impact

Seat Location	Seat Position	Left No. Occ.	Left Avg. AIS	Center No. Occ.	Center Avg. AIS	Right No. Occ.	Right Avg. AIS	Total No. Occ.	Total Avg. AIS
Front	GM	3	2.00			1	6.00	4	3.00
	Ford	2	2.00			2	5.50	4	3.75
	Chrysler	1	6.00					1	6.00
	All	6	2.66			3	5.67	9	3.67
Rear	GM								
	Ford								
	Chrysler	1	1.00			1	1.00	2	1.00
	All	1	1.00			1	1.00	2	1.00
Total	GM	3	2.00			1	6.00	4	3.00
	Ford	2	2.00			2	5.50	4	3.75
	Chrysler	2	3.50			1	1.00	3	2.67
	All	7	2.43			4	4.50	11	3.18

APPENDIX J

Table J-1. Number of Injured Body Regions per Occupant by Side of Impact and With and Without Side Beam Severe Intensity Restrained Drivers

Body Region	With Side Beam Left Impact	With Side Beam Right Impact	Without Side Beam Left Impact	Without Side Beam Right Impact
Internal Organ				.40
Brain	.25	1.00		.60
Face	.25			.60
Head	.25	1.00		.80
Neck	.25			.20
Shoulder Girdle	.50			
Right Upper Limb				.20
Left Upper Limb	.75			.20
Chest and Upper Back	.75	1.00		.80
Lower Back				
Abdomen	.25			.40
Pelvic Girdle	.50			.40
Right Lower Limb	.25			.60
Left Lower Limb	.25			.60
Whole Body				
Not Applicable				
Total	4.25	3.00		5.80
No. Occupants	4	1		5

Restrained: 42% of SI Group Drivers
With: 50% of Restrained SI Group Drivers
Without: 50% of Restrained SI Group Drivers

Table J-2. Number of Injured Body Regions per Occupant by Side of Impact and With and Without Side Beam

Severe Intensity
Unrestrained Drivers

Body Region	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
Internal Organ			.40	.17
Brain			.20	.33
Face	1.00	1.00	1.00	.33
Head		.50	.60	.17
Neck	1.00		.40	.17
Shoulder Girdle			.20	
Right Upper Limb			.60	.17
Left Upper Limb	1.00		.20	
Chest and Upper Back	1.00	1.00	.60	.33
Lower Back	1.00			
Abdomen			.20	.17
Pelvic Girdle				
Right Lower Limb			.20	
Left Lower Limb			.40	.33
Whole Body				
Not Applicable				.17
Total	5.00	2.50	5.00	2.33
No. Occupants	1	2	5	6

Unrestrained: 58% of SI Group Drivers
With: 21% of Unrestrained SI Group Drivers
Without: 79% of Unrestrained SI Group Drivers

Table J-3. Number of Injured Body Regions per Occupant by Side of Impact and With and Without Side Beam
Severe Intensity
Restrained Right Front Passengers

Body Region	With Side Beam Left Impact	With Side Beam Right Impact	Without Side Beam Left Impact	Without Side Beam Right Impact
Internal Organ				.50
Brain				1.00
Face				1.00
Head				1.00
Neck				
Shoulder Girdle				
Right Upper Limb				
Left Upper Limb				
Chest and Upper Back				1.00
Lower Back				.50
Abdomen				.50
Pelvic Girdle				1.00
Right Lower Limb				1.00
Left Lower Limb				.50
Whole Body				
Not Applicable				
Total				8.00
No. Occupants				2

Restrained: 20% of SI Group RFP
With: 0%
Without: 100% of Restrained SI Group RFP

Table J-4. Number of Injured Body Regions per Occupant by Side of Impact and With and Without Side Beam

Severe Intensity
Unrestrained Right Front Passengers

Body Region	With Side Beam		Without Side Beam	
	Left Impact	Right Impact	Left Impact	Right Impact
Internal Organ			1.00	.33
Brain		.50		.67
Face		.50	1.00	.67
Head	.50			.33
Neck	.50			.33
Shoulder Girdle				.33
Right Upper Limb			1.00	.33
Left Upper Limb		.50		
Chest and Upper Back	.50	.50		.67
Lower Back	.50			
Abdomen	1.00	.50		.33
Pelvic Girdle		.50		.33
Right Lower Limb				
Left Lower Limb				.33
Whole Body				
Not Applicable				
Total	3.00	3.00	3.00	4.67
No. Occupants	2	2	1	3

Unrestrained: 80% of SI Group RFP
With: 50% of Unrestrained SI Group RFP
Without: 50% of Unrestrained SI Group RFP

APPENDIX K

Table K-1. Index to Case Numbers in the Side-Impact, Side Damage Subset of Automobile-to-Automobile Collisions Organized by Collision Intensity Group, Side of Impact, and With and Without Side Beam

With Side Beam		Without Side Beam	
Left Impact	Right Impact	Left Impact	Right Impact
Moderate Intensity Collision Intensity Group 1			
CAL 71 127A	CAL 71 324A	CAL 71 329A	AA 166
OK 107	HSRI 584	CAL 71 449A	CAL 71 451A
OK 265 72	UNM 69	CAL 71 450A	HSRI 204
	RTI 095 67	CAL 70 418	HSRI 606
	SWRI 7193	GIT 260 105	MCR 70 7
	UM 623 72	MCR 69 12	OK 134 72
		MMF 70 18	OK 179
		UNM 26	OK 196
		RAI 111	RAI 71
		SRI 2 007 1	SWRI 6905
		SWRI 6905	SWRI 6917
		SWRI 7183	SWRI 7019
		UC 500	UOK 72 1
Collision Intensity Group 2			
CAL 71 155a	CAL 71 301A	CAL 71 281A	MVD 5
CAL 71 284A	CAL 71 336A	CAL 71 306A	MVD 13
GIT 260 102	CAL 71 468A	CAL 71 351A	CAL 71 13A
HSRI 213	GIT 260 10	CAL 71 359A	CAL 71 160A
HSRI 238	OK 037	CAL 71 568	CAL 71 238

Table K-1 continued

With Side Beam		Without Side Beam	
Left Impact	Right Impact	Left Impact	Right Impact
OK 184	OK 060	HSRI 363	CAL 71 271A
OK 191	OK 224 72	HSRI 487	CAL 71 358A
SWRI 7148	OK 232	HSRI 543	CAL 71 411A
UM 444 71	OK 330	HSRI 891	CAL 71 E1A
UM 692 72	OK 371 72	MCR 70 1	CAL 71 4B
	OK 399 72	UNM 81	GIT 260 108
	OK 444 72	OK 043	HSRI 544
	OK 497 73	OK 045	MIAMI 72 207
	SWR 72 15 2	OK 483 72	OK 012
	UC 1305 D	OSU 9	OK 016
	UM 534 71	RTI 95 56	OK 055
	UM 642 72	SWRI 7210	OK 130 71
		TU 71 20	OK 195
		UC 560	OK 299
		UM 319 70	OK 361
		UM 386 70	USC 71 4
		UM 607 72	USC 18
		UM 694 72	SWRI 7024
		UM 704 72	SWRI 7164
			UC 532
			UM 488 71
			UM 638 72
Collision Intensity Group 3			
CAL 70 46B	CAL 71 38A	CAL 71 1A	CAL 71 147A
CAL 71 104B	CAL 71 162A	CAL 71 215A	CAL 71 227A
MIAMI 72 208	CAL 71 41B	CAL 70 39B	MCR 69 5
USC 71 2	HSRI 206	CAL 71 52B	OK 154

Table K-1 concluded

With Side Beam		Without Side Beam	
Left Impact	Right Impact	Left Impact	Right Impact
UC 533	HSRI 518	HSRI 864	OK 427 72
	HSRI 880	MIAMI 72 205	RTI 6
	OK 054	OK 287 72	321 KY 01
	OK 127	RTI 95 83	
	OK 180	RAI 138	
	OK 204	SWRI 71 38	
	UM 647 72	SWRI 71 61	
		TU 71 28	
		UM 569 71	
Severe Intensity Collision Intensity Group 4			
UNM 75	CAL 71 371A	OK 088	CAL 70 56B
SWRI 7207		UC 1183D	GIT 260 100
			OK 079
			RAI 116
			SWRI 7189
			UC 1003D
			UC 1172 D
Collision Intensity Group 5			
MIAMI 72 204	RAI 81	MI 6970 08	BU 70 22
OK 406 72	SWR 7213 2	SWRI 6903	OSU 22
UM 626 72		SWRI 7191	TU 42I 16 70
			UC 559

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